ELEMENTARY SCIENCE TEACHING ACTIVITIES

A Discovery Laboratory Approach

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PREFACE

Elementary teachers have a tremendous responsibility in preparing tomorrow's citizens. The foundation you will begin with your pupils in arithmetic, social studies, language arts, science, and the arts will go with them through life. How will you form the foundation in science?

To teach children science, not only must you know science subject matter, but you must know the nature and the methods of science. To read about science is one thing, but it is something else to learn about science in the laboratory—making measurements, moving balance weights, and devising experiments. You cannot learn to play a piano merely by reading about piano playing. You cannot learn to swim by reading a book about swimming. You cannot learn about science by reading a science book. You must become involved in the act of doing. By experimenting in the laboratory, you not only begin to get a real knowledge of science and laboratory techniques, but you also begin to gain an understanding of the nature of science. Is this important?

The answer to this question may be found in another question: What is science? The spirit and process of inquiry in science cannot be taught through telling and it cannot be learned by listening; science involves activity.

Do you think you have a "fear" of science? Many elementary teachers say that they feel inadequate in science. Why is this? Perhaps they do not understand the nature of science. Many of those who "fear" science have confused technology, a product of science, with the purposes and processes of science. Perhaps this is the source of their frustrations; they have tried to memorize "all about technology." But most of the facts of technology known in 1900 are not usable facts today. What will be the important facts when your pupils leave school? To study facts alone is a questionable use of time. To spend your time teaching useless facts is an extravagant use of your pupils' time. To believe that we learn science by thinking about science, therefore, is inefficient. To get to know is to participate in what is known. So, your pupils do not learn science from your "talking about" or "reading about" science. Learning starts with a pupil interacting with his environment. In this interaction a problem may develop. But, how will he interact? Will he look up the answer in a book? Will he ask you? Or will he put his question to nature? You, as his teacher, cannot further your pupil's understanding simply by talking to him.

Dr. Piaget, an eminent Swiss psychologist, has said that good teaching must involve presenting pupils with situations in which they put their questions to nature—trying things out to see what happens, manipulating things and symbols, posing questions and seeking their own answers, comparing what they find one time with what they find at another time, and comparing their findings with findings of other children. When your pupils do this, regardless of the outcome, you can then say your pupils know.

Therefore, an important objective for you, as an elementary teacher, is to learn how to use and teach this method in inquiry, sometimes called the scientific method. An objective of this manual is to give you an opportunity to use the scientific method as you get the "feel" of science in the laboratory.

It has been stated above that how a student goes about solving a problem is probably more important than the answer he obtains. However, you will find that most of the laboratory work will deal with particulars, and many of the investigations will be structured. If knowledge resulting from a laboratory experience is to have validity, some structure must be provided. In this manual some investigations are explicit to enable you to proceed with the investigations without relying on other aids. In other more advanced investigations less structure is provided as you acquire basic skills. These advanced investigations will provide the opportunity to try things out for yourself—manipulating, posing questions, and seeking your own answers. The particulars are important; they serve as vehicles through which learning takes place. This, in fact, is a second goal of this manual for you: To gain competence in science concepts.

You have identified two goals that you will wish to achieve in the laboratory: (1) to gain an understanding of the nature of science, and (2) to gain competence in science subject matter. These two objectives are combined to form your third objective. Using the knowledge gained from objectives (1) and (2), objective (3) is to provide opportunities for children in your classes to gain understanding and knowledge of science.

These are the objectives for you, but how will this manual help you to achieve them? The uniform format of this manual is designed to serve as a helpful procedural guide. It is based upon a standard sequence of each investigation. Following each section below is a short description of the section:

Introduction: The introduction "sets the stage" for the laboratory. The introduction also gives information which may be necessary for proper understanding of the laboratory.

Problem: The problem states in concise question form what you expect to learn.

Materials: A list of equipment and expendables to be used in the investigation.

Procedure: The procedure may simply be step-by-step directions, but other methods may be employed when they seem more suitable.

Questions: The questions are designed to help you discover the significance of the investigation. Because some of the questions will go beyond the scope of the investigation, it will be proper for you to use your readings and previous knowledge with your laboratory results when forming your answers. Questions are placed throughout the investigations and at the end of each chapter.

Opportunity for Inquiry: This section gives you the opportunity to explore basic problems on your own. You will gain a deeper understanding of scientific methods and concepts from this section. The investigations in this section will be less structured.

Demonstrations, Further Research: This section contains a number of short demonstrations that may be of value to you in teaching elementary science. If time permits, you may wish to try a few of these each period.

How will you begin each investigation or experiment? It was stated earlier that you will ask nature to answer your questions; you will not ask your instructor. Remember that you get answers only if you know how to ask questions. This is

true of asking man or asking nature to answer questions. Therefore, you must come into the laboratory prepared, not only with an understanding of your question, but with some idea of how to go about finding the answer. You must read not only the section in the manual but any other sources that may be of value. And, you must read them *before* you enter the laboratory. It may help you to prepare notes or outlines in advance of the investigation, particularly if you will collect data. A chart or graph may help you record and interpret data. In collecting data, remember that if nothing happens, this too, is data and should be recorded. A recorded "nothing" is sometimes just as significant as "it turned red and bubbled." Therefore, record *all* data that you observe. Record only what you observe, not what you think you should observe and not what your neighbor observes.

When your experiment or investigation is over, clean your work area with a damp paper towel or sponge. Make sure all gas and water outlets are properly turned off. Return all equipment and supplies to their designated storage area. A good rule to remember is to leave the laboratory area as you would like to find it.

Finally, no investigation or experiment is complete until it is accurately reported. A fact is sometimes defined as "a statement describing an occurrence that is based upon many observations." If you report an occurrence as a fact in your lab report, another person should be able to observe the same occurrence. If the person is not with you when you perform your experiment, he must rely upon your report. Then the essence of a good laboratory report is this: The report should be written clearly enough that an uninformed person could read the report, know exactly what you were trying to do, how you tried to do it, what conclusions you reached, and if necessary, be able to duplicate the experiment using your report alone for a guide. The following is a general form suggested for writing laboratory reports. A separate report should be written for each laboratory, as well as for each inquiry.

(1) *Title*—The name of the experiment.
(2) *Purpose*—The objective of the investigation or the problem of the experiment.
(3) *Procedure*—A very brief outline of the method you used in the experiment or investigation, stated in your own words.
(4) *Data*—Measurements, with proper units; labeled diagrams; and graphs, with titles and labels.
(5) *Conclusions*—Based upon data.

You will probably wish to keep your laboratory reports in a separate notebook with your answers to the questions at the end of each chapter. This notebook will serve not only as a basis for evaluation, but will also serve as a basis for review. Some of the activities in this manual may be applicable for your classroom teaching, but they are intended mainly for you—a prospective elementary teacher—to help you gain an understanding of basic science concepts through scientific inquiry.

CONTENTS

INTRODUCTION

A Psychological Basis for Science Teaching

Piaget has stated that experience is always necessary for intellectual development. The activities involved in this manual are of two sorts: 1) learning about the content and the nature of science, and 2) learning how children comprehend this content at various stages of their intellectual (cognitive) development, ages 0-15. To show how children's intellectual development varies, there is a brief section in the first part of the manual introducing the stages of mental development as determined by Piaget, Inhelder, and their co-workers at the Institute of Genetic Epistemology in Geneva, Switzerland. This section is followed by a series of exercises involving the laws of conservation of mass, volume, and probability to be done with children.

STAGES OF COGNITIVE DEVELOPMENT

Children's minds are not adult minds. Children do not see nor understand things in the same way as adults. They have had neither the experiences nor have they developed the mental patterns of thought to react to problems in adult fashion. Teachers have realized that there is a great gap between the way they think and the way their pupils think. However, because of a lack of understanding of how to compensate for these differences, teachers have tended to require children

to behave mentally in adult fashion. Furthermore, this lack of understanding has caused teachers to invest great effort in teaching only to have it result in little progress and permanent learning.

Piaget's psychology has provided a classification of mental processes in a hierarchy helping one become aware of children's mental development and thought patterns. An accumulated body of knowledge from the field of child psychology has revealed that children's intellectual development evolves through stages as they progress from early childhood to adolescents. An awareness of these stages and the characteristics of children in each stage can do much to provide guidelines in devising learning experiences commensurate with the child's intellectual ability. There are four stages of cognitive development. They are as follows:

1. *Sensory-Motor Period* (0-2 years)

This is a period of organization of physical actions; order and organization begins. The child begins to form rudiments of cognitive activity in his mind which are organized progressively into more elaborate schemes as he develops. He begins by adapting his innate reflexes to the objects around him and coordinating the various actions to learn the object's properties. He touches, feels, pushes, and slides the objects about him. Later he may learn to use these properties in solving practical problems. As he develops and uses his mind, he is finally able to recall mentally the properties of these objects without having to test them.

At the end of this period he is able to imagine. The child can call to mind certain people, animals, objects, and activities. By age 2, he has "names" for many things and activities enabling him to begin to elaborate his concepts in the next stage.

Space is limited in the "sensory motor child" to the area in which he acts, and time is limited to the duration of his actions. Progress develops as he becomes more involved with activities concerning space and time.

He is mainly directed by outside stimuli until the end of the sensory-motor period. The child cannot perform any operation mentally without actually performing it physically at the same time. He has no imagination for objects or acts. He cannot add, subtract, or even classify unless he is acting on real objects. These procedures only become meaningful to him in the next stage of mental development. Even the most rudimentary sense of direction and purpose does not develop until well into this stage. He is unable at this time to detour or remove an obstacle without forgetting where he is going.

2. *Preoperational Stage* (2-7 years)

This is the *intuitive stage;* the child is *stimulus-limited.* He is no longer operating just on stimuli from the environment. Now he is able to form mental images and to label them verbally. He also attaches labels to objects present around him, although this does not indicate that he has developed a logical classification system. For example, he may call an object long one time and big or small another time depending on whether the length or width strikes him. The preoperational stage is said to be intuitive because, as the child develops, he begins to sense mentally the difference between such things as an individual item and its class, singular and plural, some and many, man and men, and "daddy" and other men. When he is able to classify and coordinate with

ease, he will have moved on to the next stage of mental development.

He centers his attention usually to one or another dimension of a problem. He may see only the features that stimulate him the most. For example, if you take a ball of putty and roll it out, the child will tell you that it has become bigger—he centers on length. However, he will not notice that the putty is also thinner; he has not decentered his attention to include width.

He *focuses* on *states instead* of *mental transformations.* A preoperational child cannot combine a series of events to show how the changes they have undergone unify them. For example, if a child is shown a series of pictures of a pencil falling and asked to order them in the way the pencil fell, he cannot do it. He can only visualize the state of the pencil before and after it has fallen. He cannot perform the mental transformation of thinking of pictures in the mind as a mental series.

His *thought processes are not reversible.* If a preoperational child is asked: "What is a chicken?" He will say, "It is a bird." Then, if asked, "What would happen if all the birds were killed? Would there be any chickens left?" He will probably reply, "Yes." The child does not realize that the subclass chicken belongs to the class bird. If the class is destroyed, then the subclass is also destroyed. For him to grasp this point, he would have to have a good idea of class and subclass, plus the ability to reverse his mental processes of class inclusion.

The *understanding* of *chance* and *probability* is absent. Children in the preoperational stage are only beginning to form genuine ideas of chance and probability, which become stable in the next stage.

Animistic explanations are common. The child of this period is animistic and artificialistic in his view of the world. An example of an artificialistic explanation is the following: If you ask him how a crater was formed, he is likely to say that it was formed by a giant. If you ask him why an object falls he is likely to give you an animistic explanation by saying: "It moves because it wants to."

He is egocentric. It is difficult for a child of this period to understand views other than his own. He talks, for example, with little attention given to whether he is being understood or even listened to. He has no concept of several points of view. He thinks a game can have only one set of rules. A word can have only one meaning and the word is equivalent to the object. For example, he is likely to think the sun was always the sun for everyone, because people could tell by looking at it. There is only one truth and the parent or teacher knows it. Considerably later in his life, he realizes that it is by mutual agreement that rules, definitions, and hypotheses are reached.

His time concept has expanded over the previous stage. His impression of time has changed from the immediate present to where he can think of future and past time. His understanding of time, however, does not extend very far beyond the present.

3. *Concrete Operations (7-11 years)*

In the concrete operational stage, the child is able to perform mental operations. The mental maneuvers are now incorporated into a system with inner rules that enables them to be called operations. In order for these operations to be performed, they require the presence of the object and are, therefore, concrete. His thoughts are stimulus-related. The object of the stimulus now brings to mind all the possible things

he can do with it in an orderly manner. The order is the mental operations that make a system. If he rolls out modeling clay, he is simultaneously aware that he can reverse this operation.

Class and relation concepts are devised. One of the main outcomes of this stage of development is that the child constructs class and relation concepts in which he can more effectively order what he encounters in the world. He conceptually organizes his environment through cognitive structures—organized ideas. Each new encounter with nature does not require extensive examination. He can go beyond things and think of groups. This ability to form classes and groups enables the child to expand his mental activity greatly.

Limited hypotheses are possible. The child who demonstrates one property of an object tends to pose to himself hypothetically the other possible properties by being aware of the relations between the properties. For example, if a child is given a number of matches and asked whether there will be more or less when they are spread out or grouped, in this stage of concrete operations, he is able to realize that the numerical properties stay the same. In the preoperational stage, however, if you spread the matches out, he will probably say either there are more because they take more space or that there are less because they are less dense. The concrete operational child, however, knows that the number remains constant regardless of how you move the matches.

His understanding of space and time are greatly expanded. Now the child can classify and arrange events in historical sequence. (He can now place in order a series of pictures of a falling pencil.) He can visualize that space is composed of measurable events.

The child of this period can mentally represent several related actions simultaneously. While he performs a real action, he can bring to mind simultaneously a set of related possible actions. For example, if he pours water from a wide flat jar to a slender jar, the water level in the slender jar will be higher. If the concrete operational child is asked whether there is more or less water in the slender jar than there was in the wide jar, he will reply, unlike the preoperational child, that it is the same. If you ask the concrete operational child why he thinks this is true, he will probably reply: "If you return the water to the wide jar, you will have the same volume as before showing no loss or gain in the water level." The concrete operational child poses mentally the possibility of the action of refilling the wide jar with water. The significant accomplishment is that when he thinks of the properties of any object, rather than being diverted by each, in turn, he tends to think of all of them as a group.

4. *Formal Operations (12-15 years)*

This period is the development of abstract and reflexive thinking. The child is stimulus free; he can go beyond the actual situation and perform abstract thoughts.

Reflexive thinking processes begin. The formal operational child begins to think like an adult. He can think back on a series of mental operations—reflexive thought. In other words, he can think about his thinking. He can represent his own mental operations by symbols.

Probability becomes understandable. The child can think in terms of many possibilities rather than being limited to the facts before him. He can think of ideals as opposed to realities.

The thinking processes become more hypothetical—deductive. He formulates hypotheses as testable ideas in his mind

and does not think of them necessarily as realities. Because of his capacity for abstract thought, he can derive the principle underlying actual situations and deduce from them hypotheses to verify their correctness. The child is capable of working at the same time with principal ideals and abstract concepts on the one hand and actual objects, procedures, and situations on the other.

The process of abstraction becomes more developed. The child of this period is more at ease with mathematical abstraction and manipulation. Dr. Flavel says:

> "In brief, the adolescent can deal effectively not only with the reality before him . . . but also the world of pure possibility, the world of abstract, propositional statements, the world of 'as if'. This kind of cognition is adult thought in the sense that these are the structures within which adults operate when they are at their cognitive best, i.e., when they are thinking logically and abstractly."[1]

The above summary of the intellectual development of children is admittedly very brief, but it should give you a viewpoint that will be of considerable assistance in teaching science. Interest in the cognitive development of children has been accelerating among psychologists, scientists, and science educators over the last decade. As a consequence, many modern science curriculum projects give greater attention to the child's cognitive development. These projects include: *The Illinois Studies in Inquiry Teaching, The Science Curriculum Improvement Study at the University of California, The Elementary Science Study at Watertown, Massachusetts, The American Association for the Advancement of Science, Commission on Science Education, K-6 Materials, The Madison Project of Syracuse University and Western College*, plus many others in science.

A word of caution should be given concerning use of the model of child development presented in the previous pages in respect to the age grouping. Individuals vary considerably and it is quite possible that a unique individual may manifest certain mental patterns of thought outside the period indicated. Furthermore, the material presented comes from research studies of children as they are and not as they might be. If children have enriched and well designed experiences, their mental development might vary from the age categories of Dr. Piaget, but the sequence of mental stages would probably remain the same.

There is a considerable question among curriculum developers as to whether the cognitive development of the child can be accelerated. A definitive answer to this question does not seem possible at present. Whether mental development can or cannot be accelerated does not seem as important as providing experiences for developing rich and fluent thinking within each of the cognitive stages. The paramount concern of teachers, therefore, should be the designing of experiences for children to insure that they have opportunities to perform and practice activities appropriate to their level of cognitive development. For example, if children are to develop into good problem solvers, they must have many opportunities to use their minds to solve problems. Science teaching can offer a width of problem-solving activities that can con-

[1]John H. Flavel, *The Developmental Psychology of Jean Piaget*. Princeton, New Jersey: D. Van Nostrand Company, Inc., 1963, pp. 86-87.

tribute to providing opportunities for children to use and develop their minds. The very nature of behaving scientifically requires one to be a problem solver. The development of teaching practices to provide for a cognitive development presents a great challenge, but it is well worth the endeavor.

The following exercises in the first section of this manual develop some understanding of the cognitive differences of children at different age levels. They have been modified after the classic experiments of Dr. Piaget. The experiments generally involve problems children have in understanding conservation of volume, mass, quantity, and length. They particularly help to show how children's conceptualizations vary from those of adults. The replication of these studies have been among the most revealing and rewarding experiences prospective and experienced teachers have had in our classes. These experiences will contribute considerably to understanding how the child views the world and give a better realization of some problems in teaching science. These exercises are such that they can easily be done at home or in some other non-academic environment where a child is more likely to be available. Class time probably will not be used for collecting the data for these exercises, but will be used to discuss findings and their implications for teaching science. Not all exercises need to be done by all students in your class. They probably will be divided among the members of your class by your instructor; you will pool your information at the conclusion of your examinations with the children.

EXERCISE 1
SENSORY-MOTOR STAGE OF COGNITIVE DEVELOPMENT
(0-2 years)

1. Observe a child of the sensory-motor stage. Describe in as accurate and scientific terms as possible the actions of the child you observe.
2. The child of this period is said to be stimulus limited. Devise some activity with the child to determine why this statement is made by Piaget. Record your observations.
3. Attempt to delimit how far the child maintains his interest from his immediate environment. Record your observations.

EXERCISE 2
PREOPERATIONAL STAGE OF COGNITIVE DEVELOPMENT
(2-7 years)

Conservation of Mass

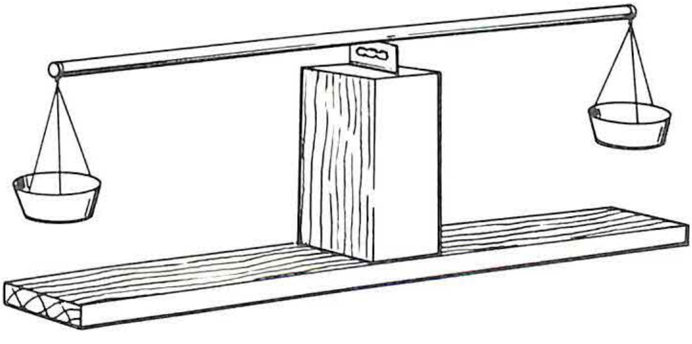
Conservation Laws

The conservation laws are basic laws of science and usually are taken for granted by adults. Children of the preoperational stage, however, seldom have any conceptualization of the laws of conservation and often demonstrate almost unbelievable reactions when confronted with problems involving them. The

mental processes used in understanding the conservation laws of volume, mass, distance, and matter involve thinking of some quantity that is conserved or unchanged while undergoing some transformation.

For example, in the conservation of mass problem below, the putty A is rolled to form putty B. Its weight (mass) remains the same while its length becomes longer, but the width becomes shorter. Preoperational children tend to center on one aspect of this transformation. Knowing this, predict their responses before you perform the following conservation investigation. Later in the manual you will perform scientific investigations involving the law of conservation. You will be alerted to this fact by a reference to conservation concepts. In the problems that follow, determine at which age children begin to understand conservation of matter, mass and volume. Record your findings and keep for use later in the manual.

1. Obtain about a half a pound of putty or modeling clay and a balance.
2. From the putty, form two equal blocks in weight. Place them on the balance to be sure they are equal. If you do not have a balance, a simple one may be easily constructed. Obtain a single-edged razor blade, a small block of wood, a 6-inch length of 2×4 wood beam, a wooden rod, some stiff wire, and an aluminum pie pan. Take the single-edged razor blade, insert its sharp side down into the block of wood until half of the blade is in the wood. Attach the small block to the dowel and cut from the aluminum pie pan two small trays equal in weight. Place these trays as indicated in the diagram. Balance the dowel with the trays on the 2 by 4, as shown in the diagram. The 2 by 4 can be nailed to another board to give it stability.



3. Obtain some children in the preoperational stage of development and place one block of putty on the pan of the balance. Ask: "What do you think will happen if I place the other block equal in size on the other end of the balance?"
4. Place the other block of putty on the balance. Ask: "What do you notice about the balance? Are the two pieces of putty equal?"
5. Take one of the blocks off the balance, roll it so that it is sausage shaped. Ask: "What do you think will happen to the balance when the sausage-shaped piece of putty is placed on it?"
6. Place the sausage-shaped putty on the balance. Ask: "Why do you think the sausage-shaped putty balanced?"

7. Record your findings and bring them to class for discussion. Explain why you think you got these reactions.

EXERCISE 3
COMPARISON OF PREOPERATIONAL (5-7 years) AND CONCRETE OPERATIONAL (7-11 years) STAGES

The following should be done by one or two groups in the class and the results reported to your class for discussion.

1. Get two jars, one tall and slender and one short and wide. Fill the wide jar with water. Ask a preoperational child: "What do you think will happen when I pour the water into the tall glass? Will I have more, less, or the same amount of water?"
2. Pour the water into the jar. Ask: "What happened to the water? Is there more, less, or the same amount of water in it?"
3. Repeat the investigation with several preoperational and operational children. Record the types of answers you get and explain below why you think you got those answers.
4. What conservation laws and mental process are involved in understanding the above activity?

EXERCISE 4
COMPARISON OF PREOPERATIONAL AND CONCRETE OPERATIONAL STAGES

1. Collect 10 straws or match sticks or pencils. Clump them together and then separate them so they are wide apart. Ask: "When are there more or fewer straws—when they are together or far apart? After the child answers, ask: "Have I added or taken any straws away?" After the child answers, ask: "Now when did you say I had more or fewer straws?"
2. Explain why you think you got the answers you did. What conservation law is involved in the above activity?

EXERCISE 5
COMPARISON OF PREOPERATIONAL AND CONCRETE OPERATIONAL STAGES

1. Build a tower made of cubes of different sizes, using a table as a platform for the tower. Give a preoperational child a similarly heterogeneous collection of cubes and have him build a tower of the same height as yours.
2. The table on which the child's tower is to be built should be lower than your table, and there should be a screen of cardboard interposed between the tables. Let the child look around the cardboard at your tower as many times as he

pleases. Place straight sticks of various lengths on the table with the blocks; do not give any clues to their possible use as measuring instruments.

3. Repeat the above activity with several preoperational, and concrete operational children. Record your results. Explain why you think you got the answers you did.
4. To build a tower equal in height requires a child to realize that the height cannot be accurately determined without using measuring instruments. To use the sticks as measuring guides, the child must know that he can sum the series of lengths of the sticks to equal the size of the tower he has built. Once he knows this sum he can use it to determine how high to build his tower. This activity should alert you to some of the mental processes involved in measurement and the problems children have in learning to quantify.

SUPPLEMENTAL ACTIVITIES

COMPARISON OF PREOPERATIONAL AND OPERATIONAL CHILD

The Child's Conception of Numbers

1. Give a preoperational child ten straws.
2. Have the child give you a straw each time you give him a penny.
3. After buying all the straws, spread them out on a table and place the pennies in a pile. Ask: "Are there as many pennies as straws?"
4. Repeat the above activity with concrete operational children. Record your results and explain why you think you got the answers you did.
5. If the preoperational child says there is inequality between the straws and pennies, can you suggest any perceptual reason why he might do so?

To perform this activity properly, children must first understand the meaning of numbers. They must also know that numerical equality exists between two sets (one set being the straws and the other set the pennies) when a mental operation of a one-to-one correspondence is performed.

FORMAL OPERATIONAL (11-14 years on)

Involved in the following investigation is a study of how children at different intellectual stages conceive of chance or probability. The following activity involves going from non-randomness to randomness. In order to understand this operation, the child must realize that the process of mixing is not reversible. You should determine at what stage this understanding occurs.

1. Obtain a small shallow box, 5 red, and 5 white marbles. Line the marbles up so that the 5 white ones are on one side and the 5 red ones are on the other side.
2. Ask a preoperational child: "What will happen to the marbles when I tilt the box?" Draw what will happen to each marble.
3. Tilt the box. Repeat the tilting several times until the marbles have been randomized.

4. Repeat the above procedure with concrete operational and operational children. How does the ability to predict differ with preoperational, concrete operational, and formal operational children?

Teacher's Note on Chance and Probability

Before a child understands probability or chance, he learns some things are certain and some things are not certain. Once he has this understanding, he can move to degrees of certainty. In the process of forming these mental impressions and outlooks, he is learning that there are operating in nature certain laws in some instances while at other times these apparently are not laws. The haphazard mixing of marbles may seem a case of "non-lawness" to him, although to a scientist randomness itself is a law. The preoperational child does not distinguish well between chance and non-chance. In the concrete operational stage there is a progressive distinction as to what is possible and what is certain. The child of this stage recognizes chance operations, but has not looked at the situation as involving combinations and proportions. How are the marbles likely to combine and in what proportion will the white mix with the red?

The child of the formal operation stage is more likely to demonstrate an understanding of degrees of certainty plus performing the mental operation of combinations or proportions.

PART I

PHYSICAL SCIENCE

1

Preliminary Investigations

How does a laboratory investigation differ from an experiment? If you were to observe a scientist involved in a laboratory investigation, you would discover two phases of the scientist's methods. One is the collection of information (data) and attention to what is happening, called an investigation. This has been the typical activity in science classes. The students knew the conclusion in advance of the investigation and the activity was simply to verify or illustrate some principle. This procedure of laboratory work is fundamental to scientific activity, but it does not give a complete picture of the nature of science to the students.

One activity of a scientist is to collect data—to investigate nature. This may lead to another type of activity that requires simple reasoning from what is observed. The data may be collected until a number of relationships are observed. A generalization may be drawn from these relationships. This type of reasoning is called inductive reasoning. Another type of reasoning is called deductive in which you start with a principle and reason that if it is true, then certain consequences must follow. You then set up an experiment to test the consequences.

A scientist investigates by collecting data; then, he may reason or think about these data. His reasoning may be either inductive, deductive, or both. In any

case, he may set up an experiment to confirm or disprove his reasoned hypothesis. An experiment utilizes a control, a duplicate activity with only the factor being tested as different. The control is set up to check and compare the results of an experiment. It gives the experiment an objective basis for comparison and, thus, an objective basis for testing reasoned hypotheses.

An *experiment* is an activity to confirm or disprove an hypothesis. An investigation is an activity to verify what is known or to gain new skills. In the first three laboratories you will gain new skills to help teach elementary school science. In the other twenty laboratories you will gain an understanding of science concepts and the nature of science. These experiments assume that you have a limited science background. By design of the manual, some of you may experience some frustration at first until you become accustomed to this method of learning. You will not always be told answers; you must seek them from nature. Your instructor may answer your questions with other questions, designed to direct your thinking. This is necessary if you are to understand the nature of scientific inquiry. Have you ever tried to describe the taste of coffee? Try it! Before the person will know what coffee tastes like, he will have to experience tasting the coffee. The same is true of the spirit and process of science; no one can describe them to you, you must experience science.

THE SCIENCE LABORATORY

The key to successful teaching of science in the elementary school depends on the preparation of teachers familiar with the laboratory and its facilities. Through several experiences with methods of inquiry, you can develop your personal understanding of the nature and methods of science and, more importantly, the skills that instill confidence in your ability to use the discovery approach in teaching science concepts to children. The experiences described below are designed to further orient you with the science laboratory.

You will soon learn to use simple devices for measuring lengths and masses in the English and metric systems, such as rulers and balances of various kinds. Now you have an opportunity to learn about the use, care, and purchase of science equipment and materials and how several instruments are commonly used to make observations and to obtain data about natural phenomena. Initially, however, you must pay attention to one very important aspect of the laboratory concerning the continuing necessity for both *knowing* and *practicing* principles of safety.

Safety in the Laboratory

Teachers cannot place too much emphasis on safety practices in science teaching. As each demonstration or activity is planned, safety precautions should be considered in setting up and handling material and equipment. Prevention, rather than remedy, of accidents commands our constant attention. Study the following precautions and suggestions for your own safety, that of your classmates, and that of your future students. Note that the following list is not exhaustive and you will have to exercise common sense in meeting other situations.

(1) Accidents, no matter how slight, should be reported immediately to the teacher.

(2) If you do not understand the

instructor's oral or written directions, ask questions until you are clear about what you are to do.

(3) Observe safe-operating limits for all equipment and take special note of labels and directions that advise caution in using. (Children should not handle equipment, materials, animals, or plants without permission.)

(4) When using sharp instruments, be careful to cut away from you—never toward your, or another person's, hands or body.

(5) Severe cuts may be suffered from broken glass. Never attempt to insert glass rod or tubing having jagged ends into a rubber stopper or tubing—always fire polish the glass tube first. Use water, soap, or glycerine to lubricate the glass rod or tubing. Wrap a piece of wet cloth or paper towel around the hand or tubing at point of contact with the hand to avoid injury if the glass breaks. Hold the glass tubing as close as possible to the part where it is entering the rubber stopper. Aim the glass tubing away from the palm of the hand which holds the stopper or rubber tubing. Remove glass rod, thermometer, or tubing from rubber stopper or rubber tubing to prevent sticking.

(6) Strong acids and bases cause severe burns. Never add water to these chemicals in diluting them—always add the concentrated acid or base to the water to prevent splattering and sputtering. If acid or base is spilled anywhere or contacts your clothing or skin, *first* flush liberally with plain water and then tell your teacher who will use a solution of baking soda to counteract an acid or vinegar to neutralize a base.

(7) Keep bottles of chemicals labeled properly at all times. Use caution in smelling or tasting chemicals. Many are poisonous! Avoid prolonged breathing of fumes from volatile liquids, such as alcohol, ether, chloroform, benzene, etc., and do not use inflammables in a room where there is an open flame.

(8) Use care in making electrical connections. Ask your teacher to check your setup before using electrical devices.

(9) Dispose of excess chemicals, broken glass, or other materials in proper containers. Ask your teacher if in doubt about proper disposal.

(10) Finally, clean all equipment and glassware after use and return it to its usual storage place.

Using Science Equipment and Materials

A convenient way of organizing your knowledge about the use of various pieces of equipment is to indicate the type of energy to which they are sensitive. The various forms of energy are: (1) atomic or nuclear, (2) chemical, (3) electrical and magnetic, (4) heat, (5) mechanical, such as potential and sound energy, and (6) radiant, such as light and radio waves. Can you think of several instruments used to detect and measure these forms of energy? Using the types just mentioned, make a chart by listing, under each type, several such instruments, as in the following example:

Atomic-Nuclear	Chemical	Electrical-Magnetic	Heat	Mechanical	Radiant
Geiger counter	Thermometer	Ammeter-Voltmeter	Thermometer	Pressure gauge Audiometer	Radiometer Thermometer

What do you notice about the instruments listed thus far in the above chart? The fact that the thermometer is listed under more than one form of energy shows that energy may be converted from one form to another. For example, any form of energy may be transformed into heat and detected by a thermometer.

Problem:

What is the difference between heat and temperature?

Procedure:

A good starting point for learning more about instruments in science is various sources of heat and the thermometer. Obtain two or more of the following heat sources: alcohol lamp, candle, Bunsen burner, electric hot plate, propane torch, etc. Find out which gives more heat. How can you tell? Why? What factors govern the rate of burning? How may these be adjusted in the Bunsen burner to provide the highest temperature of the flame? What regulates the amount of heat given off by an electric hot plate? Try heating a needle in various positions in different heat sources. What part of the flame is at the highest temperature? Draw a sketch of a flame to indicate its various parts. Try heating toothpicks held in various parts of a flame. Where does the toothpick catch fire the quickest? Does the amount of oxygen or the temperature of various parts of the flame have the greater influence on the kindling temperature of the toothpick?

Obtain a thermometer and two beakers of the same dimensions. Fill one beaker almost full and the second beaker one-half full of a liquid and heat them separately over the *same heat source.* While some student teams are doing the following experiment with water, others might try glycerine or other liquids. (Consult and obtain these from your instructor.) Use measured quantities. Use the thermometer (or even better, a stirring rod) to stir the liquid carefully. Record the temperature of the water at 30-second intervals until the liquid begins to boil. Plot your data on a graph. Compare the temperature of the liquid in the two beakers at (a) 1 minute, (b) 2 minutes, (c) 3 minutes, etc. What conclusions can you draw from the data obtained in this experiment? Can you make any predictions from the data? If so, give examples.

Compare your graphed data with that of other student teams. How can you explain the differences?

Which beaker of liquid gets hot faster? Why?

Obtain a block of wax or paraffin and several samples of *different* metals the same size. Heat the metal pieces in a beaker of boiling water. Remove the pieces quickly with a pair of tongs and place in different spots on the block of wax. Which piece of metal melts the wax faster? Which melts more wax?

QUESTIONS

1. What do the last two experiments show about the amount of heat different substances have or hold? By what name is this concept known?

2. What is the difference between heat and temperature?
3. Of what different kinds of materials or forms of matter are thermometers made?
4. How do each of them operate? To what different uses are they put?
5. What advantages and disadvantages do different thermometers have?
6. To what *sources of error* are each of these kinds subject?
7. Investigate the different kinds of thermometer scales in common use. Which scale is used in scientific work?
8. How can you convert temperatures from one scale into another?
9. What is the difference between the function of a thermometer and the function of a calorimeter?

Problem:

To become familiar with the apparatus and supplies commonly used in elementary school science teaching.

Unless a student sees and understands the various purposes for which science equipment and supplies may be used, these items will remain confusing. It may be seen that in addition to *measuring* various quantities and *observing* changes in energy, scientific equipment and supplies may be used to *collect* and *preserve*, *display*, and *experiment*. In addition to these processes, scientists also build systems of *classification*, evaluate evidence, infer, predict, recognize space-time relations, recognize number relations, and communicate their results to the world. Other integrated processes are used in more advanced scientific work.

Procedure:

Examine the samples of chemicals, glassware, and hardware displayed on the demonstration table. Make three separate lists of the (1) chemicals, (2) glassware, and (3) hardware commonly used in elementary science teaching. For what different purposes are these things generally used in teaching science concepts? Can you think of other uses for any of these that are rare or unconventional? Here is your chance to be creative! How may less expensive items of plastic or paper be substituted for "regular" equipment or materials? Styrofoam plastic may be easily worked to form many shapes. To what novel uses might you put this material to help in teaching elementary science concepts?

Further Investigation

One of the functions of the science teacher is to obtain materials and equipment needed to demonstrate or to involve students in the investigations of various science concepts. You will find a variety of science supply company catalogs in the laboratory. Examine several of these.

Suppose you want to teach a unit on a given science topic. Determine what items you will need for a class of, say, twenty-four pupils and make out a requisition or order for these items.

LABORATORY 1
HEAT SOURCES

Introduction

There are four or five types of heat sources used in an elementary school science class: hot plates, candles, alcohol lamps, propane torches, or Bunsen burners. Of these, only the Bunsen burner and the propane torch may be used for a wide variety of uses. The Bunsen burner produces temperatures that may reach 1500° C and the propane torch may produce temperatures much higher. The other three heat sources do not lend themselves to manipulating glass tubing, nor to any other activity requiring a high temperature. In this laboratory exercise you will be using only a Bunsen burner or a propane torch, but you should also be familiar with the use of hot plates, candles, and alcohol lamps.

The Bunsen burner is named after its inventor, Robert Bunsen, a German chemist. There are varieties of Bunsen burners, but their differences are in appearance only.

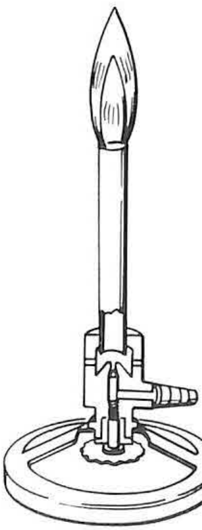
The working principle of the Bunsen burner is very simple: gas entering the burner through a hose and air through the air adjustment are mixed in a favorable ratio in the barrel of the burner to provide complete burning of the gas.

To provide a favorable ratio of gas and air, the burner usually has two adjustments: an air adjustment and a gas adjustment. On Bunsen burners without a gas adjustment the gas flow must be controlled by the main gas cock. Burners with gas adjustments control the gas supply by a notched wheel on the bottom of the burners.

The air is adjusted on different burners either by means of a movable collar at the base of the burner barrel, a lever at the bottom of the burner, or by simply raising or lowering the barrel by twisting it right or left.

Problem:

(1) How are laboratory burners adjusted for use in the laboratory?
(2) What is the hottest and coolest part of a burner flame?



Materials:

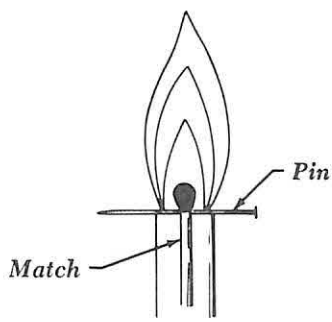
Equipment
Bunsen burner
Propane torch (optional)
Iron wire from coat hanger
Pins, straight
Paper, stiff white

Expendables
Matches

Procedure:

Work in teams of two or as directed by the instructor.

1. Determine the function of each part of your Bunsen burner. If possible, take your Bunsen burner apart, then reassemble it. Record your description of the burner parts and tell the function of each part.
2. Connect the Bunsen burner to a gas outlet. Strike a match and bring the burning match to the burner top. Hold the match just above and slightly to one side of the barrel opening. Why? Turn the gas on fully and shut off the air intake. Regulate the gas flow on the burner by the gas control or the gas cock.
3. Slowly open the air intake. Record what changes you notice in the flame.
4. Regulate the air intake until the flame takes the form of two cones. The inner cone should be a bright blue color and the outer cone a pale blue color. The inner cone should be about 5 centimeters high and the outer cone about 10 centimeters high.
5. Try to determine which part of the flame is the hottest and which part the coolest. Place an iron wire in different parts of each cone. Record how much time is required for the wire to glow with red heat in different parts of the cone. Record your results by drawing a diagram of the flame and show where the flame is most hot and where it is least hot.
6. Investigate what effect gas pressure has on the flame. Increase and decrease the gas pressure by regulating the gas control on the burner. Record your results.
7. Investigate a propane torch. Repeat procedure 5 to determine which part of the propane flame is hottest.
8. Try the following investigations with a Bunsen burner:
   (a) Hold a piece of stiff white paper vertically and quickly thrust it into the flame, just above the burner. When part of the paper becomes charred, quickly remove it from the flame. What can you conclude about the burner flame from this?
   (b) Stick a straight pin through a match, just below the head of the match. Place the match, head up, into the burner barrel so that the pin rests on the top of the barrel and the head of the match is protruding above the barrel. Light the burner. Be careful not to touch the match head with the flaming match. What can you conclude about the burner flame from this investigation?



9. The data section of your laboratory report should include a sketch of a burner flame with the time required for a wire to glow in different parts of the flame as well as your data from procedure 8. Your conclusions should be based upon these data.

QUESTIONS

1. Describe in your laboratory report any other observations you have made about the Bunsen burner and its functions.
2. Was your study of the Bunsen burner an investigation or an experiment?

LABORATORY 2
CONSTRUCTING A WASH BOTTLE

Introduction

As a primary teacher, you may demonstrate that "air takes up space" by pouring water through a glass tube that goes through a one-hole stopper into a flask. How would you construct the apparatus? How would you cut the glass tubing?

As an upper elementary teacher, you may demonstrate "atmospheric pressure" by constructing a simple barometer. How would you cut the glass tube to make the barometer? How would you close one end of the tube?

This investigation is designed to give you an opportunity to gain skill in the manipulation of glass tubing. The wash bottle, which you construct, will be used in Laboratory 4, *Chemical Change*.

Problem:

(1) How is glass tubing cut, polished, drawn, and bent?
(2) How is a glass tube inserted through a stopper?

Materials:

Equipment
File, triangular
Meter stick
Burner
Flask, 250 ml.
Stopper, 2-hole, #6½

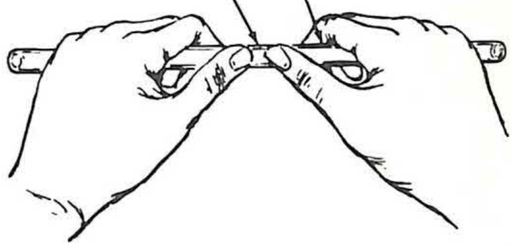
Expendables
Glass tubing, 50 centimeters

Procedure:

Work individually or as directed by the instructor.

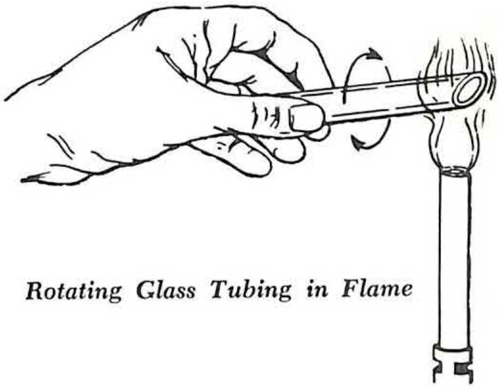
1. Cut *one* 30-centimeter length of glass tubing and *two* 10-centimeter lengths of glass tubing. The 30-centimeter tube and one of the 10-centimeter tubes will be used to make a wash bottle. The other 10-centimeter tube will be used to make a stirring rod.
2. Glass tubing may be cut by the following procedure: First, place a length of glass tubing parallel to and near the edge of a table. Hold it firmly with one hand. In your other hand, place a triangular file with its flat side up.
3. Place the triangular file on the place where the tubing is to be cut. Pressing down firmly, draw the edge of the file toward you. A "gritty" sound will be heard if this is done correctly. This is done to make a deep scratch in the glass tube.

4. Pick up the glass tube with the scratch away from you. Place the thumb of each hand a little to each side and opposite the scratch as shown in the illustration on the right.



Breaking Glass Tubing

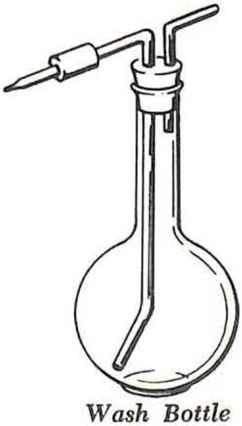
5. Apply pressure with the thumbs while pulling the tubing apart with each hand, as though you were trying to bend the tube. Do this quickly and the tube will break cleanly at the scratch.



Rotating Glass Tubing in Flame

6. The freshly cut edges of the tube are sharp and must be smoothed by fire-polishing. Fire-polishing is the technique of removing the sharp edges by melting the edges in a flame until they are smooth. The end of the glass tube is held in the hottest part of the flame and rotated as shown in the illustration. Rotate one end of the tube in the flame until the edges soften and become rounded, but do not fire-polish so long that the end of the tube begins to close. Fire-polish one end of the 30-centimeter tube and one end of one of the 10-centimeter tubes. Place the tubes on an asbestos mat or wire gauze to cool. *CAUTION:* Hot glass looks like cool glass and glass cools slowly. Be careful with glass tubing that has just been heated. After five minutes, fire-polish the opposite ends of the tubes.

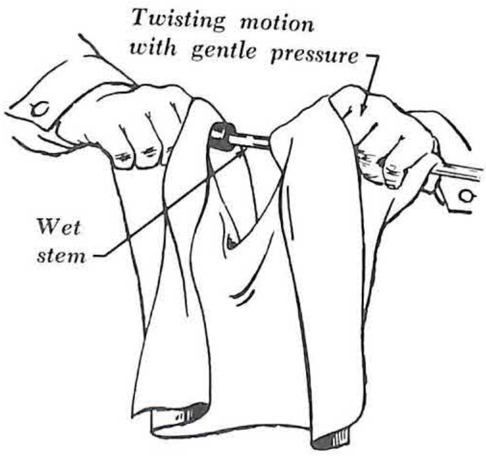
7. Notice the nozzle on the end of one glass tube of the wash bottle on the right. This nozzle must be made *before* bending the tube. In order to make glass nozzles, "eye droppers" or capillary tube, the following procedures may be followed: Pick up the 30-centimeter glass tube. Heat the tube about 5 centimeters from one end in the hottest part of the burner flame.



Wash Bottle

Rotate the tube and move it back and forth to heat the tube in a uniform manner. Continue heating the tube until the glass becomes soft enough to sag. Remove it from the flame and draw it to the desired size with a determined pull. Place the tube on an asbestos mat or wire gauze to cool. When the tube is cool enough to touch, cut it to the proper length and fire-polish the ends. (OPTIONAL) The short tube may be made into a pipette by flaring the larger end. Soften the larger end in the burner flame and press it on an asbestos mat. A rubber bulb may then be attached to the flared end (when it is cool) to make a dropping pipette.

8. You are now ready to bend the tubing to make a wash bottle. Bending a glass tube requires heating a considerable portion of the tube. Use a wing tip on the burner. Heat the tube at the bending point by rotating it back and forth in the burner flame as you did to make the nozzle. Continue heating the tube until the glass becomes soft enough to bend under its own weight. Remove it from the flame and immediately bend by *raising* the ends of the tube to obtain the desired angle. Study the illustration of the wash bottle, then bend the glass tubing into the desired shapes.
9. To complete the wash bottle you must pass the glass tubing through a stopper. First, moisten both the end of the glass tube and the edges of the hole in the stopper. Water (or Glycerine) will serve as a lubricant to reduce friction. Next, wrap a piece of cloth or paper towel around your hands. Take hold of the tube near the stopper and push it with a gentle twisting motion.



Inserting Tubing into Rubber Stopper

CAUTION: Be very careful. Do not force the tube. Keep your hands close together near the stopper so that if the tube breaks, you will not cut yourself when your hands move together.

10. Complete your wash bottle and test it. Fill the flask about half full of water. Blow on the short tube and direct the stream of water into a sink or a container.
11. The remaining 10-centimeter glass tube will be your stirring rod. Fire-polish

both ends of the tube until they close completely. If you wish, you may identify your stirring rod by writing your name on a small piece of paper and sliding it into the center of the tube before closing the ends.

12. Since this laboratory is intended only for skill acquisition, you will have no data nor conclusions in your lab report.

LABORATORY 3 MEASUREMENT

Introduction

Science has one characteristic that makes it different from other disciplines, such as history, music, or literature. This is the characteristic of measurement. A famous British scientist of the nineteenth century, Lord Kelvin, had this to say about the role of measurement in science:

> "I often say that when you can measure what you are speaking about, and express it in numbers, you know something about it; but when you cannot express it in numbers, your knowledge is of a meagre and unsatisfactory kind; it may be the beginning of knowledge but you scarcely, in your thoughts, have advanced to the stage of 'Science', whatever the matter may be."[2]

Measurement always involves comparing the thing being measured with some standard scale or unit of measurement.

Where do these standards come from? Where does the foot come from? The yard? The meter? The pound? The day?

Selection of measuring standards is frequently quite arbitrary, such as the designation of the "foot" as the length of a king's foot.

On the other hand, some measuring standards are based upon certain natural events or units. For example, the meter is one ten-millionth of the distance from the equator to either pole, and the day, of course, is the period of rotation of the earth.

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[2]Gerald Holton and Duane H. D. Roller, *Foundations of Modern Physical Science*. Reading, Mass.: Addison–Wesley Publishing Company, Inc., 1958, p. 229.

Part A

Problem:

How do you measure the length of a rectangular solid object?

Materials:

Equipment

Unmarked strip of paper, one inch wide and approximately notebook length

Block of wood or a textbook

Procedure:

1. Establish that the strip of paper of arbitrary length is your *standard unit of length*. Give it any name you wish, such as "strip" or "paper."

2. Divide the strip into equal subdivisions by folding and marking with a pencil. How many subdivisions will you make? Keep in mind that you will be adding, subtracting, multiplying, and dividing measurements made with this standard.
3. Measure the length of your book or block using the standard. Record your answer to the nearest whole unit and subdivision. Is your result exactly a whole unit? Is it exactly one whole unit plus a whole number of subdivisions?
4. How can you increase the accuracy of your measurement? Would further minor subdivisions of the standard be helpful? If so, place them on the paper standard. How many minor subdivisions will you make within each larger subdivision?
5. Re-measure the book or block using the revised standard. Is the measured length an exact number of whole units, subdivisions, and minor subdivisions? What should be the next step in getting an accurate measurement of the length of your book or block? Is it acceptable to include an estimated value in your measurement? What fraction will you use for your estimated value? What influences your choice here?
6. Compare your standard unit with that of a classmate. Establish a conversion factor between your standard and his standard. What useful purpose does this serve? Compare this with the situation in real life between two different systems for measuring length. How do you decide which is a more appropriate standard?

Part B

Problem:

How do you measure the weight of an object?

Materials:

Coil of Chromel wire
Ring stand or other support rod
Small objects, such as paper clips, pennies, keys, erasers, etc.
Thread and ruler

Procedure:

1. Weight is the force of gravitational attraction between the earth and other objects. To measure this force, a small spring can be used because it can stretch a certain amount with a certain force. Fashion a small coil spring by carefully wrapping a two-foot length of Chromel wire around a pen or pencil. The spring should be approximately three inches long finished with a small hook at each end.
2. Hang the spring from the ring stand support by using the thread. Set the ruler vertically beside the spring. Note where the bottom of the spring is in relation to the ruler. Use the same reference point on your spring for each measurement of weight.

3. Calibrate the spring by hanging uniform-sized paper clips on it. Start with one, two, three, etc., noting exactly where the reference point matches up with a mark on the ruler. Keep a record as follows:

Number of Paper Clips	Stretch (units of length)
1	
2	
3	
etc.	

Do not extend your spring too far. Check the calibrating by removing paper clips one at a time. Does the spring resume its original position each time?

4. Plot a graph with stretch on the horizontal coordinate and number of paper clips on the vertical coordinate. What kind of a line do you get? From your graph, could you predict what the weight of an object is in paper clips if you knew the amount of stretch of the spring?
5. Weigh the other small objects, such as the penny, key, eraser, etc. Record the weight in "clips." Do your weights come out in whole numbers? How can you make your weighings more accurate?

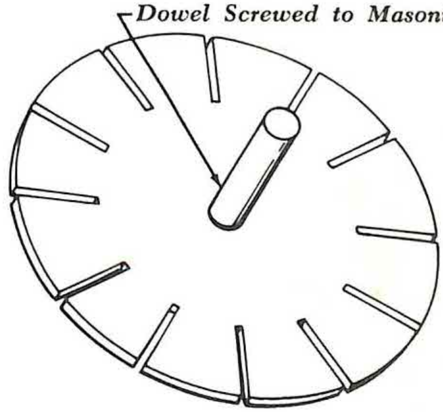
Part C

Problem:

How can you measure short intervals of time?

Materials:

Hand stroboscope
Electric fan, electric bell, or other object which rotates or vibrates at a high rate of speed
Stop watch or watch with sweep second hand



Hand Stroboscope

Procedure:

1. Work with a partner. Determine the number of slits per second passing the eye when the stroboscope is turned at a moderate rate.

2. Using the stroboscope, view the vibrating or rotating object and calculate its rate of rotation or vibration.
3. How will you determine when you have obtained the correct measurement? Might your answer be a multiple or fraction of the correct number?
4. How can you improve the accuracy of this method of measuring the rate of rotation or vibration of an object?
5. Express your results both in terms of rotations or vibrations per second, and in terms of times required for one rotation or vibration. Which is the more useful expression? Why?

Reference:

Manual for Measurement Science.
Ohaus Scale Corporation
1050 Commerce Avenue
Union, New Jersey 07083
1965

Part D

Problem:

How can you measure liquids in metric units of measure?

Materials:

Equipment	*Expendables*
Graduated cylinders (assorted)	Masking tape
Test tubes (assorted)	Drinking straws

Procedure:

1. Fill a graduated cylinder with colored water.
2. Using a drinking straw, remove one milliliter of water by holding your finger tightly on the top of the straw.
3. After marking the level for one milliliter on the straw, use the straw to transfer ten milliliters of water from a beaker to a test tube which has a piece of masking tape attached to it lengthwise.
4. Mark the liquid level in your test tube along one edge of the tape.
5. Empty your test tube and repeat step 3 again. Mark the liquid level on the other edge of your tape.
   a. Did both of your measurements come out about the same?
   b. Compare your results with someone near you. Are your results about the same?
6. Several graduated cylinders have been placed on the tables around you. Pour the 10 milliliters of liquid from your test tube into one of the graduated cylinders.

a. Is the calibration on your cylinder accurate?
b. If not, what may account for the inaccuracy?

This lesson may be expanded to mark further graduations on the test tube. The test tubes can then be used to measure the capacity of some common containers, such as half-pint milk cartons or pop bottles. Conversions will still have to be learned, but the measures will be more meaningful and you will have learned some useful laboratory procedures as well. Similar exercises can be developed for the other metric measures.

LABORATORY 4
CHEMICAL CHANGE

Introduction

In Laboratory 1, you found that unless sufficient air is supplied to a Bunsen burner, the flame is yellow and smoky. If you were to hold a cool plate above this flame, carbon (a type of soot) and water would form on the plate. Upon burning, gas changes into at least three substances: carbon, carbon dioxide, and water, which have different compositions than gas or air, the starting materials. This type of change, in which new products are formed, is called a chemical change.

So far, you have become acquainted with several kinds of laboratory apparatus and several laboratory techniques to aid you as an elementary science teacher. In this investigation, you will not only have the opportunity to gain skills, which you may need, but which you will teach to your pupils. If your pupils are to gain the ability to ask questions of nature, then they must know the basic techniques and methods used to gain answers.

Problem:

How are the balance, graduated cylinder, ring stand and iron ring, stirring rod, and Bunsen burner used in the laboratory? For what purposes are they used?

Procedure:

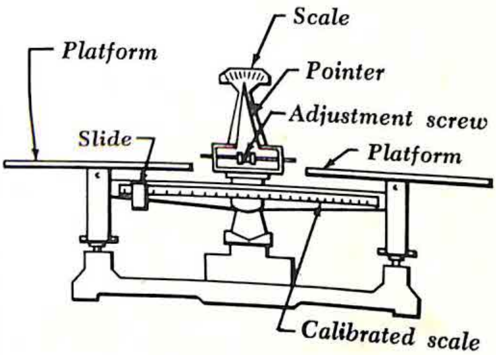
Work in teams of two or as directed by your instructor. If you work as a team, plan your investigation so that one member is acquiring equipment while the other is getting equipment ready. As part of a team you have the responsibility of doing your part well. After reading the following procedure, set up a convenient form on which to record data. You may wish to use a form as illustrated below.

DATA

a. Mass of dry beaker . . . . ________ gram
b. Mass of weighing paper . . . . ________ gram
c. Mass of weighing paper and sodium bicarbonate . . . . ________ gram
d. Mass of sodium bicarbonate ($c - b$) . . . . ________ gram

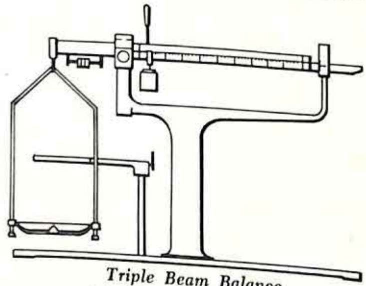
e. Mass of beaker and sodium bicarbonate $(a + d)$. ________ gram
f. Mass of beaker and dry substance (after evaporation) . . . . ________ gram
g. Mass of dry substance $(f - a)$ . . . . ________ gram
h. Loss or gain of mass $(g - d)$ . . . . ________ gram

1. Obtain a 250-ml. beaker. Find the mass of the beaker and record its mass to the nearest 0.1 gram.
2. Many laboratories have either a triple-beam balance or a platform balance. Determine if you are using (a) a platform balance or (b) a triple-beam balance and read the appropriate section below.
   a. *Platform Balance*
   A platform balance has two platforms. The object whose mass is to be found is placed on the left platform. On the right platform are placed masses judged to be slightly less than that of the object. A sliding mass on the scale is then moved to the right until the platforms are in equilibrium. A pointer moves to the zero mark on the scale when the arms are in equilibrium. The mass of the object is the sum of the masses on the right platform plus the mass represented by the sliding mass. Your instructor may wish to give you more specific directions for using your particular balance.

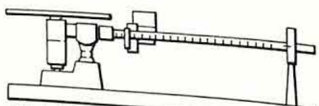


Platform Balance

   b. *Triple-Beam Balance*
   The triple-beam balance may have a pan suspended from an arm or it may have a platform resting on top of the arm. In either case, the arm has three divisions on the right side of the balance. The object whose mass is to be found is placed in the pan or on the platform. The largest mass on the arm is then moved to the notch which is just too far, then moved back one notch. Follow the same procedure for the medium mass. The sliding mass on the arm is then moved to the right until the pointer indicates equilibrium has been reached. The mass of the object is the sum of the masses indicated on the three beams. Your instructor will give you more specific directions for using your particular triple-beam balance.

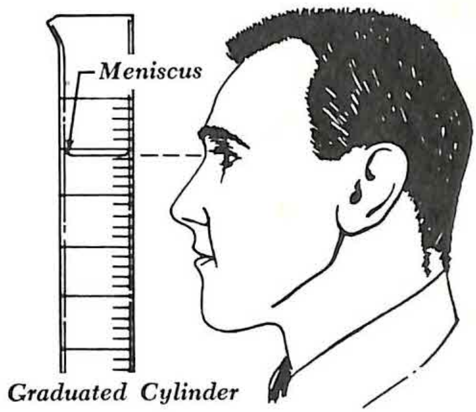


Triple Beam Balance (Suspended Pan Variety)



Triple Beam Balance (Platform Variety)

3. Put 1 gram of sodium bicarbonate ($NaHCO_3$) on the balance. Chemical substances should never be poured directly on the balance. A container, such as a square of paper, must be provided. Tear a sheet of notebook paper into four equal pieces. One piece of paper will be used on the balance. The other sheet of paper will be used to transfer the sodium bicarbonate from the stock bottle to the balance. Crease the paper in the middle. Tap about one teaspoon of sodium bicarbonate onto the creased paper. Transfer the sodium bicarbonate onto the paper on the balance by tapping the creased paper with your index finger. Do not forget to consider the mass of the paper. Record the mass of the paper and also the mass of the sodium bicarbonate with the paper.
4. Place the sodium bicarbonate in the beaker.
5. Measure 25 ml of hydrochloric acid (HCL) with a graduated cylinder. *CAUTION:* Acid can cause skin burns. Should you spill acid on yourself, immediately wash with large amounts of water, neutralize with a sodium bicarbonate solution. (Cover the bottom of a beaker with sodium bicarbonate and add just enough water to dissolve. Pour this solution over the area.) Inform your instructor. When liquids are poured into a tube, such as a graduated cylinder, they form a curved surface called a *meniscus*. Always read the bottom surface of the meniscus, as shown in the illustration. Note: If you find it necessary to pour acid into a sink be sure to have water running. Acid will attack the plumbing if not diluted.



6. Obtain your stirring rod. Slowly pour the 25 ml. of acid onto the sodium bicarbonate in the beaker, stirring as you pour. Stir the liquid several minutes after all the acid has been poured.
7. Some of the solution may be on your stirring rod and must be returned to the beaker. Using your wash bottle, direct a fine stream of water over the end of the rod. Do this over the beaker so as to catch the water. Use only a small amount of water from the wash bottle.
8. Obtain an iron ring, ring stand, burner, and wire gauze. Place the iron ring on the ring stand and place the wire gauze on the iron ring. A wire gauze must always be used when heating glass containers. A beaker or flask may crack if exposed directly to a flame. Why? Place a burner under the iron ring. Adjust the iron ring to about 15 cm. above the top of the burner. Place the beaker containing the solution on the wire gauze on the iron ring. Light the burner. Heat the solution slowly.
9. When only a small amount of solution remains, reduce the size of the flame under the beaker. Continue heating slowly as the solution may pop and splat-

ter if heated too rapidly at this point. If time does not permit completion of the evaporation, allow the beaker to cool before placing it in the storage area.

10. When *all* water has been removed from the beaker, record the mass of the beaker and the dry substance. What is the mass of the substance in the beaker? To find its mass subtract the mass of the beaker (obtained in procedure 1) from the mass of the beaker and its contents. How does this mass compare with the mass of the sodium bicarbonate you started with? What would account for any difference?
11. Save the dry substance in the beaker for Laboratory 5.

LABORATORY 5
OPPORTUNITY FOR INQUIRY: CHEMICAL IDENTIFICATION

One of the major purposes of science teaching is to develop children's ability to comprehend the nature of science and the processes of science. One method you may use to reach this objective is to give your pupils an opportunity to participate in science, seeking their own answers. The most effective learning results from situations in which the learner is actively involved. However, the activity must have meaning for the students; repetition of cookbook laboratory work by the pupils does not give as true an impression of the nature of science as will be obtained when you give them an opportunity to do scientific inquiry.

A scientific inquiry, or the scientific method as it is sometimes called, may be defined as an attempt to describe the activities of a scientist as he solves problems. Some have tried to categorize the scientist's thought processes into five or six steps. It is doubtful that any two scientists solve any two problems alike, let alone use a series of steps to solve a problem. They are probably not aware of any one method in seeking answers to problems. Although there is not one scientific method common to all of the science, there are certain mental activities (observation, inference and comparison, analysis and synthesis, imagination, supposition and idealization) used by individuals in scientific investigations. Identify these mental activities as you seek understanding through the following inquiry.

In this and other opportunities for inquiry you should organize your procedure. Remember, if you intend to get an answer you must know how to ask a question. What questions could you ask after finishing procedure 10 of Laboratory 4? How about "Where did the white substance come from?" This question could be asked, but could you find the answer? In this and all other research, you must ask yourself, "Is my question pertinent?" There are, no doubt, many interesting questions which you could ask, but not all of these questions would you be *capable* of answering. For you must also ask yourself, "What observations are needed to help me obtain an answer?" You should consider which methods you have available to help you obtain your answers. For example, consider the above question, "Where did the white substance come from?" How would you go about seeking your answer? It is clear that this question is not pertinent, for no method exists by which to seek the answer. Questions must involve something that is tangible and must be worded in such a way that

an inquiry can answer the question. In general, "what" and "when" questions are more readily answered than "how" or "why" questions.

Stating a pertinent problem capable of being answered with available methods is probably one of the most important skills of inquiry. Now, how about restating the problem like this— "What is the white substance that was left after the liquid evaporated?" This question is pertinent, considers the observations which you make, and the methods available to assist your inquiry. Therefore, here is a question stated for you to find an answer. Future inquiries may find you stating the problem on your own.

The next step of an inquiry may be to form a statement or intelligent guess of the answer. What is your guess (hypothesis)? Is the white substance crystallized sodium bicarbonate? Or, is it a different compound? Will the chemicals used give any clue? What happened when the hydrochloric acid (HCl) was added to the sodium bicarbonate ($NaHCO_3$)? You should attempt to form several hypotheses. How can you find which of your hypotheses is correct?

The next step of your inquiry may be to test your hypothesis on the basis of relevant data. You may already know that different chemicals have different physical properties. Color, crystal form, physical state, density, and hardness are a few of the properties observed readily.

Place some sodium bicarbonate on a piece of paper. Place the white substance beside it. Pick up a pinch of sodium bicarbonate between your thumb and index finger and rub together. Compare what you "feel" with what you "feel" with the other substance. What do you observe? What causes this? Compare the two substances under a hand lens or a microscope. Describe the shape of the crystals. If the crystals are not large enough to see, you may wish to "grow" larger crystals of each substance. How is this done? Check several reference books to see if you can identify the white substance from its crystal structure. What is the white substance? How do you know? Your laboratory report should include a statement of the problem (purpose of the experiment), a statement of your hypotheses (in the procedure), a table or list of data and information and where you obtained the data (data section), how you tested each of your hypotheses (procedure), and a statement of the conclusion you reached from testing each hypothesis (conclusion).

Return all equipment to the storage area, but save the glass tubing for future experiments.

2

How Does Man Learn about Molecules?

You recognize many kinds of substances that make matter, such as air, water, wood, and plastic. Matter is anything that you can see, touch, taste, or smell; it occupies space and has mass. Matter may occur in three states: solids, liquids, and gases. A familiar example of matter in three states is ice (solid), water (liquid), and steam (gas).

Water (a liquid) left in an open dish will disappear after a short period of time. Where did it go? How? Moth balls (solid) placed in a closet disappear after a time and leave an odor in the air. What happened to the moth balls? Water sometimes appears on the outer surface of a cold water glass. Where did it come from? What do evaporating water, sublimating moth balls, and condensing water have in common?

The basis for explaining these changes rests with an understanding of molecular theory. A fundamental understanding of molecules is necessary not only for a study of matter, but to guide children in their interpretations of how matter be-

haves. A fundamental understanding is required if you are to teach with variety. Uninspired teaching is to be avoided. Just as a young plant will be stunted if placed in dry soil, your pupils cannot learn best from dry, unvarying science lessons.

An understanding of molecules will be necessary in the following 20 laboratories; each physical science topic of the manual is considered from a molecular viewpoint, and each phenomenon can be explained by the actions of molecules.

LABORATORY 6
MOLECULAR MOVEMENT

Introduction

How large is a molecule? It is difficult to imagine the size of a molecule because it is so small. Molecules of air, for example, are so small that if each molecule in a milliliter of air (about one-thousandth of a quart) were replaced with a grain of sand the result would be a sand pile about a mile wide and a mile high. This should also give you an idea of the tremendous number of molecules involved. The same amount of water, one milliliter, contains about 30 billion trillion (30,000,000,000,000,000,000,000) molecules of water.

It is evident that many molecules are too small to be seen with the eye or even with the aid of a microscope. Molecules must be studied indirectly by observing the effect of molecules on other material large enough to see. Observations of this type, which provide information to prove a point, give indirect evidence. In this laboratory you will observe circumstantial evidence for molecular movement.

Part A

Problem:

What evidence exists that molecules are in motion?

Materials:

Equipment
Microscope
Brownian motion apparatus, or a small plastic box
Light source for microscope

Expendables
Matches
Mineral oil
Pollen grains

Procedure:

Smoke is composed of thousands of minute particles. By watching these smoke particles under a microscope, circumstantial evidence for molecular motion can be observed. A container (Brownian motion apparatus or a small plastic box) is used to protect the smoke from air currents. Place the container on the lighted stage of a microscope. Fill the container with smoke from an extinguished but smoking match. Record your observations of *one* of the smoke particles. The ap-

parent disappearance of the particles is caused by the particle moving out of focus.

If no small transparent container is available to contain the smoke, a drop of mineral oil water in which pollen grains have been suspended may be used.

Part B

Problem:

How can molecular motion be increased or decreased?

Materials:

Equipment:	*Expendables:*
Beakers, 2	Water
Burner	Ink or food coloring
Ring stand	Ice
Iron ring	
Wire gauze	
Stirring rod	

Procedure:

Molecular motion may be increased or decreased by regulating the temperature of a substance. Fill a beaker with water and place it on a ring stand over a burner flame. Heat the water until it boils. Remove the burner flame and let the water set until all bubbling stops. Fill another beaker with cold water and stir with several ice cubes.

After the bubbling has stopped in the hot water, place the two beakers next to each other. Remove any ice cubes from the cold water. When the water in both beakers is still, place several drops of ink or food coloring into each beaker. *Do not disturb the beakers.* In which beaker does the coloring seem to diffuse faster? Why?

Repeat the procedure three or four times. Do you observe the same relationship each time? What could cause different results? Devise a method of making more accurate observations. Try your new method and record all data and observations. At the end of your laboratory report, state your conclusions in terms of molecules of water.

LABORATORY 7
FORCES BETWEEN MOLECULES

Introduction

Do you know that trees and plants depend upon forces between molecules? These same forces are observed when a paper towel soaks up water. A paper towel soaks up water because of capillary action. Capillary action is also observed when one end of a glass tube, with a small diameter, is placed

in a liquid. The water rises in the tube because of capillary action. Capillary action is caused by forces between molecules.

Molecular forces cannot be seen. Their presence is known only as they react with materials. The forces that exist between molecules are evident in many ways. When similar molecules have the tendency to cling to one another, the tendency is called *cohesion*. Cohesion causes the molecules of a piece of iron to cling together. The strength of the iron is caused by the great force of cohesion between iron molecules.

The force of attraction between unlike molecules, *adhesion*, is also evident in many ways. You are familiar with an adhesive force if you have ever pulled tape from your skin. The molecules of the adhesive on the tape are attracted to the molecules of your skin.

Capillary action is caused by both cohesion and adhesion. Adhesion between the molecules of the water and the molecules of a glass tube causes water to rise in the tube. Cohesion between the water molecules causes them to cling together. You have seen adhesion in a graduated cylinder. The water clings to the sides of the cylinder causing a dish-shaped surface called a meniscus.

Part A

Problem:

How can you demonstrate capillary action?

Materials:

Equipment	*Expendables*
Burner	Glass tube, 10 centimeters long

Procedure:

Obtain a 10-centimeter length of glass tubing. (This may be cut from glass tubing scraps)

Heat the center of the tube in the hottest part of the burner flame. Rotating the tube, heat it over a wide area until it begins to sag. Remove it from the heat and *immediately* pull it three feet apart. The center section should now be stretched into a 25 to 30 centimeter length.

Place one end of the capillary tube in a beaker of colored water. Describe your observations. How does this demonstrate molecular forces?

Part B

Problem:

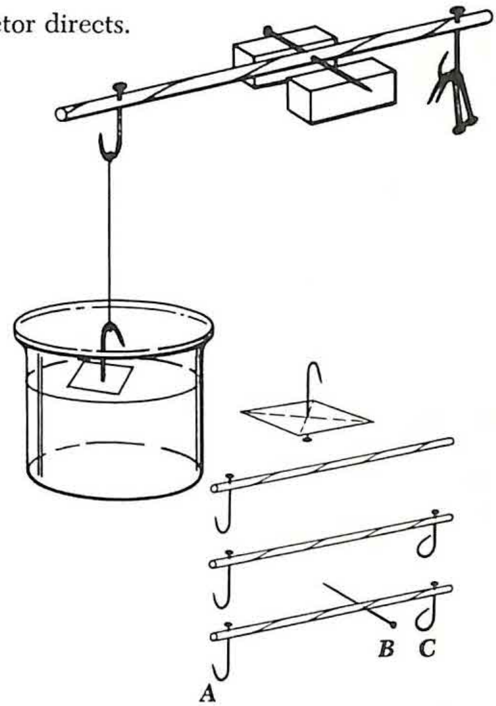
(1) Is the force of cohesion the same for different liquids?
(2) How is a graph used to represent data?

Materials:

Equipment	*Expendables*
Microscope plastic cover slips (or 2 centimeter by 2 centimeter acetate sheet)	Alcohol
Beaker	Water
Pins, straight	Soap solution
	Thread
	Pins, straight
	Straw, drinking

Procedure:

Work in teams of four or as the instructor directs.



Constructing Cohesion Balance

1. Before measuring the force of cohesion of different liquids, construct a soda straw balance. Obtain a microscope plastic cover slip. Locate the center of the plastic cover by drawing a straight line connecting the opposite corners. Stick a straight pin through this center. Bend the pin so a piece of thread may be tied to the pin.
2. Obtain a soda straw. Insert a straight pin through the straw at one end and bend the pin so a piece of thread may be tied to the pin.
3. Insert another straight pin in the opposite end in the same manner, but this time make a large bend in the pin.
4. Insert a third straight pin perpendicular to, and about a third of the distance from the pin with the large bend. Do not bend this pin.
5. Pin B will be the fulcrum of your balance. Obtain two supports (Suggestion: 2 glass microscope slides, rubber bands, piece of wood 65 × 10 × 10 mm) on which to rest each end of pin B. Connect the plastic cover slip to pin A with a length of thread. Adjust the thread length so the plastic cover slip is about 10 centimeters above the table top.
6. Move pin B, removing and sticking it in a different place, until the apparatus will balance.
7. You will measure the force of cohesion between liquid on the plastic cover slip and liquid in a beaker. Fill a beaker with water to a depth of approximately 5 centimeters. Place the beaker of water under the plastic cover slip. Lower the plastic cover slip onto the surface of the water. Gently push down on the soda straw at pin C. Record your observation. You can measure this

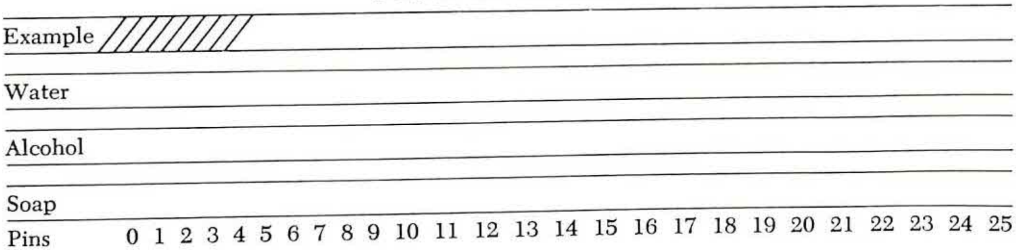
force in "pin weights." Bend 10 or 15 pins. Carefully hook the pins, one at a time, on pin C on the balance. How many pins were required to pull the plastic square from the water? Repeat the procedure three or four times and average your results. Why should you do this several times? Record all results in the data table.

FORCE OF COHESION

	Trial 1	Trial 2	Trial 3	Average
Water	_____ pins	_____ pins	_____ pins	_____ pins
Soap Solution	_____ pins	_____ pins	_____ pins	_____ pins
Alcohol	_____ pins	_____ pins	_____ pins	_____ pins

8. Repeat the above procedure using a soap solution and alcohol. The plastic square must be clean and dry before use each time and the depth of the liquid should be the same each time. Be sure to record all data in your data table.
9. Diagram the cohesive force of the various liquids on a bar graph. See the example below. The example shows that eight pins were required to pull the plastic square from the liquid. This graph could be placed in the data section of your lab report, but reference should be made of it in your conclusions. Why do scientists often use graphs to study their data?

FORCE OF COHESION



Part C

Problem:

(1) What relationship exists between cohesion in solids and forces exerted on molecules of the solid?
(2) How is a graph used to represent data?

Materials:

Equipment
Ring stand
Meter stick
Weights
Spring
Iron ring

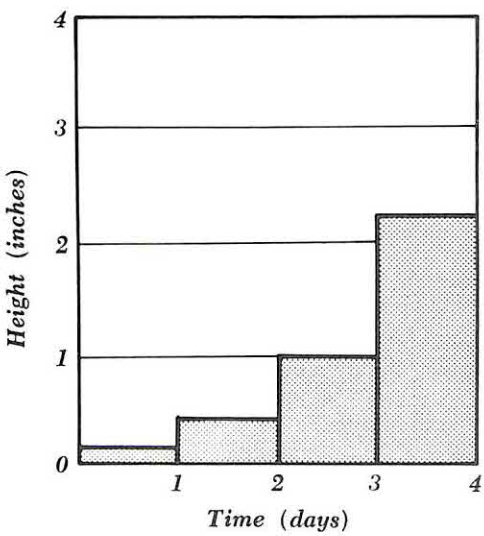
Expendables
None

Procedure:

1. Obtain a ring stand. Hang a spring from an iron ring at the top of the ring stand. Hold a meter stick on the base of the ring stand so you can measure the distance to the bottom of the spring.
2. Add masses to the bottom of the spring and measure the distance (in centimeters) from the ring stand base to the spring for each mass. Record your measurements in a data table.
3. Study your data table. What relationships exist between the masses added to the spring and the distance the spring stretched? Scientists have found that such a collection of data will show relationships much more easily if it is arranged in a graph. Obtain a sheet of graph paper. Number the spaces along the left edge of the graph in such a way that the extremes of your distance measurement will cover the length of vertical axis; the bottom number should be 0 centimeters and the top number should be the greatest length that the spring was stretched. Number the spaces above the bottom edge in such a way that the extremes of the mass you used will spread across the width of the horizontal axis; the left number should be 0 centimeters and the right number the greatest mass that was used.
4. After the measurements are equally spaced on the graph, each pair of numbers from your data table should be located on the graph and marked with an "X." Connect these points by drawing the smoothest line you can. What is the shape of the line? What does this mean? What is your conclusion concerning the distance an object is stretched and the force exerted on the object? What has this to do with molecules?

The Use of Graphs with Children

This exercise gives you an opportunity to produce two types of graphs. Graphs are used in science and in other types of communication, because they convey a wealth of information in a small amount of space and most importantly show relationships that might not otherwise be easily discovered. The building of graph understanding involves several concepts not apparent to young children. The simplest graph to start children with is a bar graph to show how a plant or a child grows with time.



Children in K-3 may see in this graph only that there is an increase in growth with time. However, children in grades 4-6 are more likely to discriminate how much the growth increases with time because they have better understanding of number, seriation, and, consequently, quantification and that time corresponds

with growth in this graph. A teacher of elementary science should give children many opportunities to construct and use graphs.

LABORATORY 8
OPPORTUNITY FOR INQUIRY: SPACE BETWEEN MOLECULES

In Laboratories 6 and 7, you observed several factors concerning molecules. You have learned that molecules are very small and moving, that temperature is related to molecular movement, and that molecules exert an attractive force on each other. This inquiry will give you an opportunity to learn another important concept concerning molecules.

Pour 10 milliliters of 95 per cent ethyl alcohol into a graduated cylinder containing 10 milliliters of water. Mix the two liquids thoroughly and record the volume of the combined liquids. Do these data raise any questions in your mind? This short procedure is intended to give you an opportunity for an inquiry. What question could be asked about these data? What lesson could you, as an elementary teacher, teach from this operation? What is your statement of the problem? Write it down now!

What do you think is the answer to your question? It is evident that difficulty will occur when you start thinking of relevant data you can collect. In some such cases an experimental model may be needed that will duplicate the observed action. You should give your imagination free play in developing models for testing. Hint: Construct a model representing water and alcohol molecules by using something to represent molecular size differences, such as beans for alcohol molecules and sand for water molecules.

Include a complete description of your statement of the problem, hypotheses, procedure used, and a statement of your conclusion in your laboratory report. Mixing the alcohol and water gives you an opportunity for an inquiry and should not be included in your report as a procedure. Your laboratory report should be concerned with reporting your inquiry.

After recording your observations, make a list of several questions raised by your observations. What are the answers to your questions? Write down several hypotheses. How can you test them? Write down a possible design of an experiment to test each hypothesis.

QUESTIONS

1. What is a molecule?
2. Describe a molecule in terms of its:
   (a) size
   (b) distance from other molecules
   (c) motion
   (d) attraction to other molecules
3. What generalization can you make about the relationship between heat and molecular motion?
4. What is the kinetic molecular theory of matter?
5. Give an example of diffusion. What does diffusion illustrate?

6. (a) Describe the forces that exist between molecules.
   (b) What evidence exists for the theory that there are forces acting between molecules?
7. It has been said that "a picture is worth one thousand words." How does a graph fit this adage?
8. Explain why it is sometimes necessary to use indirect evidence in an experiment.
9. (a) What is meant by the term "experimental model?"
   (b) How would you use an experimental model?
   (c) Why would you use an experimental model?
   (d) When would you use an experimental model?
10. How do you know you were measuring cohesion and not adhesion in laboratory 6, part B?

Further Investigation

1. Drop a crystal of potassium permanganate (CAUTION: Poison) into a tall glass jar of water. Set the jar where it will not be disturbed for several days. Observe the water each day and explain what happens.
2. Fill a water glass to the brim with water. Add a small amount of salt to the water. You know that two materials cannot take up the same space at the same time, but what happened to the salt? Does the added salt increase the weight of the water and the water glass? Explain how the water and salt seem to be taking up the same space, but are actually not doing so.
3. Build an experimental model of molecules in motion. From a drug store obtain two plastic vials, one of which will just fit inside the other. Place eight to ten B-B's inside the larger vial, and place the smaller vial on top of the B-B's. Vibrate the B-B's by placing the clapper of a ringing door bell against the bottom of the large vial. Describe how increasing the number of vibrations of the clapper will have the same effect as increasing the temperature of a gas. What causes a gas to expand when heated?
4. Stand about 15 feet from a table and have someone pour some ammonia into a dish on the table. Observe how long it takes to smell the ammonia. Repeat, using perfume, chloroform, and/or flavoring extracts. Compare the time intervals for each substance. Explain the results.
5. Make a number of very small diameter capillary tubes. See how high you can get water to rise in the tubes. Try hot water, cold water, alcohol, or fruit juice.
6. Molecular movements can be used as a research tool. After doing library research on chromatography (see also Laboratory 39, page 133), do the following investigation: Cut the part of a newspaper without print into several 20×3-centimeter strips. About 5 centimeters from the top of one of the strips, place a horizontal red mark (with water color pencil) across the paper strip. On top of this mark, place a yellow mark. Fold the paper on this mark and place it on a water glass with the short segment inside the glass and the long segment on the outside. Pour just enough water inside the glass to reach and wet the paper inside the glass. After several hours observe the paper strip. Explain your observations.

3

How Does Air Behave?

Much of the science which you will teach in the elementary school will be concerned with matter and energy. The following activities are concerned with matter in the gaseous state (air) and the energy of air molecules. These activities develop concepts that are introductory, applying mainly to areas of physical science.

How can you, as an elementary teacher, know when your pupils have achieved understanding of air pressure concepts, for example? Will a paper and pencil test indicate how well a pupil has achieved a concept? Perhaps a paper and pencil test could do this, but the real test of a pupil's understanding of a concept is his behavior when he must use the concept for interpretation. For example, if a first-grade pupil is opening a can of carbonated beverage and wishes to pour the beverage into a glass, how many holes should he punch into the can? The answer to this question will depend upon his understanding of air pressure concepts. An understanding of the concepts enables him to choose the proper number of holes from the alternatives (1 hole, 2 holes, 3 holes, etc.). Thus, the pupil's behavior will depend upon his understanding of the appropriate concepts involved.

It was stated above that air pressure concepts apply mainly to areas of physical

science. However, any of these same concepts are also basic in biology. In breathing, for example, you may use the same concepts as a study of a lift pump in physical science. This repetition of concepts has in the past presented a problem to elementary teachers. Some elementary teachers, particularly those concerned with course construction or curriculum planning, have tried to solve this problem of repetition by using a broad framework of science concepts, called conceptual themes, which draw upon all of the sciences—biology, chemistry, physics, and geology—to develop lessons. By developing this unity of the sciences, the concepts are formed into generalizations covering broad areas, thus helping the pupils to understand better the world in which they live, not just a small fraction of one part. This type of program not only gives the pupil an opportunity to acquire more realistic knowledge, but it also minimizes repetition and provides an opportunity for the early introduction of the methods and characteristics of scientific inquiry. Determine if any schools in your district use a curriculum guide constructed in accordance with this idea. Such a guide usually has several units, called themes. Learning conceptual themes helps children retain and integrate information better than merely learning a collection of facts.

Are you aware of the many different types of science programs? Investigate! Find out how the new elementary science projects differ from the traditional science programs. What advantages do the new programs have over the traditional programs? How do they differ fundamentally in their approach? Are they designed by scientists or educators or both?

LABORATORY 9
MATTER IN THE GASEOUS STATE

Introduction

Even though we live in an "ocean of air," the average person does not easily grasp concepts concerning air. We do not see or feel air unless it is in motion. However, air is matter just as water, wood, and steel are matter. Air occupies space and has mass.

Elementary teachers usually start a unit on air by demonstrating that air occupies space. An "empty" upside down water glass is pushed under water. The air, occupying space, prevents water from filling the water glass. As you observed in Laboratory 5, molecules of air are in constant motion. How is this demonstrated by air in the water glass? If the molecules of air in the water glass were not in motion the water would seep into the glass and force all of the air into one corner of the glass.

The following experiments and investigations will be concerned with the concepts of air pressure and weight of air. Answer all questions in these investigations in terms of the air's moving molecules.

Problem:

How can you show that air has weight?

Part A

Materials:

Equipment:	*Expendables*
Balloons, 2	None
Thread	
Rod, wooden, 1 meter	

Procedure:

1. Fully inflate a balloon. What is in the balloon? Draw a diagram showing the molecules in a balloon before and after inflation and the molecules of air surrounding the balloons. Tie one end of a 15-centimeter length of string around the open end of the balloon to prevent air from escaping.
2. Inflate another balloon to about the same size and tie the open end with another 15-centimeter length of string.
3. Tie the balloons, one on each end, to a one-meter length of a small, wooden rod. Tie a 25-centimeter length of thread in about the center of the rod. Support the opposite end of the string on a ring stand. Balance the balloons.
4. Puncture one of the balloons with a pin. Without moving the supporting string, try to balance the balloons. Return any balloon pieces to their end of the balance. Which balloon is heavier? Why? What can you conclude about air?

Part B

Problem:

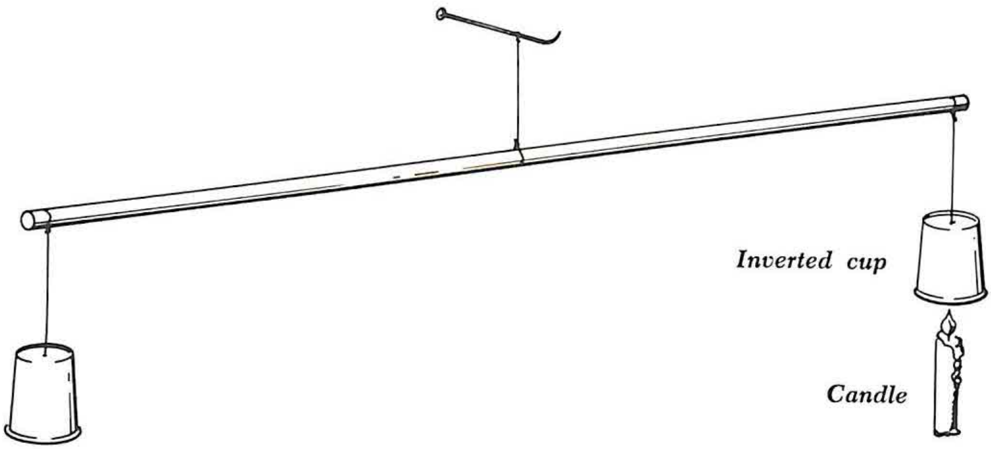
Is warm or cool air heavier?

Materials:

Equipment	*Expendables*
Wooden rod, 1 meter	Adhesive tape
Thread	Pins, straight
Candle	Matches
Cups, paper, 2	

Procedure:

1. Obtain two 15-centimeter lengths of string and one 25-centimeter length of string. Secure one end of a 15-centimeter length of string to the bottom of a cup with a straight pin. Position the pin so the cup will hang straight down. Repeat the procedure with the other cup. Tie the cups, one at each end, on a wooden rod. Tie the other piece of string in about the center of the rod. Position the string so the cups balance when the center string is supported. See the illustration below.
2. Place a lighted candle about 5 centimeters below the open end of one cup.



CAUTION: Fire. Record your observations. Which cup is heavier? Why? Record your conclusion in terms of molecules of air. You may wish to refer to Laboratory 5, Part B in your answer. Make a series of drawings to show what happens to the speed and number of molecules in each cup as the lighted candle is placed under one cup. Include these drawings in the conclusion section of your laboratory report.

LABORATORY 10
AIR PRESSURE

Introduction

In Laboratory 8, you found that air has weight. Air weighs about 1.25 ounces per cubic foot, or about 1/800 as much as the same amount of water. It has been said that we live in an "ocean of air," that extends more than 500 miles above the earth. The average depth of the waters in the ocean is about 2½ miles. In deeper parts of the ocean, the water may exert a pressure of hundreds of pounds per square inch. By comparison, air exerts a pressure of about 15 pounds per square inch.

Air exhibits several properties similar to water; both are fluids. For example, air and water both increase in weight as the depths of the fluid is increased. This weight, if measured over a certain area, is called pressure.

You have just read a number of facts about air pressure. How will you teach your pupils about air pressure? Will fact gathering and the accumulation of facts result in knowledge? The answer to this question depends upon your definition of knowledge. You may think of knowledge as an acquaintance with things and events. Or you may think of knowledge as a means to achieve understanding and maturity. If your concern for your pupils will be accumulation of facts, you will probably try to teach with a lecture-memorize-test method. However, if you are concerned with helping your pupils to reason, think for themselves, and achieve understanding, then you will probably teach by letting your pupils learn by actual experimentation. Experimentation will not only amuse and reward your pupils, but it will let them strive for achievement

and give them the feeling of accomplishment. As you perform the following investigations of air pressure, think of how you will approach the teaching of a similar unit.

Problem:

Is atmospheric pressure greater than the weight of water in a glass?

Part A

Materials:

Equipment	*Expendables*
Bottle, wide mouth	Index card

Procedure:

Fill a wide-mouth bottle with water and place a cardboard square on top. Place the bottle over a sink. Hold the cardboard firmly and flat on the bottle with one hand and slowly invert the bottle. Remove your hand from the cardboard. Record your observations. Slowly and carefully pull down on one corner of the cardboard. Observe closely and record your observations.

Fill the bottle one-half full with water and repeat the above procedure.

What was pressing down on the cardboard when the bottle was inverted? What was pressing up on the cardboard? Which force was greater? What other forces may be holding the card to the bottle? Make a drawing of the glass, water, and cardboard. Use labeled arrows to represent the various forces, making larger arrows to represent larger forces. Include the drawing in the conclusion section of your laboratory report.

Part B

Problem:

How can you demonstrate the force of air pressure?

Materials:

Equipment	*Expendables*
Ring stand	Ditto fluid can
Iron ring	
Burner	

Procedure:

Work in teams of four or as directed by the instructor.

1. Pour water to a depth of about two centimeters inside an empty and clean ditto fluid can.
2. Place the open can on a ring stand over a lighted burner. Heat the water in

the can until it boils. Continue boiling the water until steam can be seen forcefully escaping from the can. Boil the water for at least four minutes. (Why?)

3. Remove the flame from under the can and immediately replace the cap. As the can cools, record your observations. After reviewing your results from Laboratory 6, Part B and Laboratory 9, Part B, answer the following questions:
   (a) What does an increase in temperature do to molecular motion? What happened in the can when it was placed over the burner flame.
   (b) What happened to the water vapor molecules as the can collapsed?
   (c) What would have happened to the can had the lid not been replaced? How is this investigation similar to Laboratory 9, Part B, MATTER IN THE GASEOUS STATE?
   (d) What is a partial vacuum?
4. Draw a series of diagrams showing the molecules in the can and the surrounding air:
   (a) Before heating the can
   (b) After heating the can
   (c) After the cap was replaced and the can cooled

   Include the drawings with your conclusions in your laboratory report.

LABORATORY 11
OPPORTUNITY FOR INQUIRY: THE WASH BOTTLE

In Laboratory 2, you constructed a wash bottle. When you blew into the tube of the wash bottle, water came out of the other tube. What question could be asked about this operation? What lesson could you, as an elementary teacher, teach from the operation of the wash bottle? What is your statement of the problem? Write it down now!

What do you think is the answer to your question? Write down your hypothesis! Did you say that blowing into one tube increases the pressure and forces the water out of the other tube? If so, what do you mean? Blowing into the tube increases the pressure more than what? What will happen if you suck on the tube? Why? How is this related to drinking a coke through a straw?

Do the following activities to gather data and/or test your hypotheses. Think of the answers to the questions in terms of molecules and their movement.

1. Close the tube, which you blew into, by fire-polishing in a burner flame. Fill the wash bottle half full of water. Gently heat it. What happens? Why?
2. Cool the bottle with the short tube closed. Place the wash bottle in ice. What do you observe? Why does this happen?
3. Examine a mercury barometer. How does it work? Refer to reference books if necessary. How is the principle of a working mercury barometer related to the principle of a working wash bottle?
4. If the wash bottle were in a vacuum box, what would happen if you were to blow into the short tube? Why? What would happen if you were to suck on the short tube of the wash bottle? How do you know? How could you find out for certain?

Be sure to include a complete de-

scription of your statement of the problem, hypotheses, procedure used, and a statement of your conclusion in your laboratory report.

LABORATORY 12 OPPORTUNITY FOR INQUIRY: COMPOSITION OF AIR

In Laboratories 6 through 10 you learned several concepts concerning air. You have learned that air is made up of very small, moving molecules, that temperature regulates molecular movement, that air has weight which exerts a certain pressure on objects. This inquiry will give you an opportunity to learn another important concept concerning the atmosphere. You probably remember from previous science classes what substances are present in the atmosphere. The most abundant gases in the air are nitrogen and oxygen. What inquiry could you devise for your students from this fact? State the problem in the form of a question.

What is the structure of an inquiry? In Laboratory 5 you learned that an inquiry starts with a question that results from a student interacting with his environment. Stating the question is the most important part of an inquiry; if you do not ask a clear question you will not get a clear answer. In Laboratory 8, you learned that the data you collect must be relevant to the question to be of any aid in obtaining an answer. From these data you have been forming hypotheses, or "educated guesses" as to what you think the answer to your question might be. The next logical step is to test your hypotheses, one by one. The design of your test, or experiment, is important if you are to obtain a valid answer. In the following inquiry, the design of the experiment has been structured for you. Consider the concepts of experimental design as you seek to test your hypotheses for your problem.

Obtain two test tubes of the same size, a test tube holder, vinegar, steel wool, a rubber band, and a beaker large enough to hold the two test tubes. The steel wool must be of a sufficient amount to stay in the bottom of one of the test tubes when inverted.

Stuff the steel wool loosely in the bottom of a test tube and cover it with vinegar or acetic acid. Boil the vinegar and steel wool over a burner flame for a full 5 minutes. Pour off the vinegar and wash the steel wool several times with water. Drain any excess water off the steel wool and invert the test tube in a beaker about ⅓ full of water.

Set up a control experiment by placing a test tube without steel wool mouth downward in the beaker beside the test tube containing the steel wool. A control is a duplicate experiment with all factors equal except one. What is the factor not equal in the control? Place the apparatus where it can stand undisturbed until your next laboratory period.

After returning for the following laboratory period record your observations of the apparatus. Describe the appearance of the steel wool. What does the control show? What has been removed from the test tube by the process: (Hint: What is rusting?) What has taken place? Why?

Place a rubber band around the test tube containing the steel wool. Raise or lower the test tube until the water level inside the test tube is the same as the water level inside the beaker. You may have to add more water to the beaker. Position the rubber band on this water level. Being careful not to move the rubber band, remove the test tube from the beaker and clean out the steel wool. Measure the total volume

of the test tube and the volume of the test tube up to the rubber band. This may be done with water and a graduated cylinder. Record this information in the form of percentages. Use this information to complete your inquiry. Include a complete description of your statement of the problem, hypotheses, procedure used, and a statement of your conclusion in your laboratory report.

LABORATORY 13 OPPORTUNITY FOR INQUIRY: INDEPENDENT RESEARCH

You should now have a good idea of the structure of an inquiry and be ready to do independent research. Each student will make an investigation individually. You will select a problem to investigate on your own, without assistance from others. After selection of your problem, make your hypotheses, collect data, test your hypotheses, and reach a conclusion. The problem you select should consider what facilities are available for use (it will not be conducted during laboratory time), what information is available, and, of course, the problem must be of interest to you. The problem should be restricted to one particular topic and well defined, one you do not know the answer to and is not readily available in reference books.

After the problem has been approved by your instructor, determine your own procedure, collect your own data, draw your own conclusions, and report your inquiry. A spiral notebook may be used to record *all* data, including the dates and hours that work was conducted. Every observation, library reference, and any thought or ideas should be recorded. You can never tell when some seemingly unrelated bit of information may prove valuable when you write your formal report of your investigation. The spiral notebook should be handed in with your formal report.

This inquiry will be conducted at your own initiative and you cannot seek assistance from other students or instructors. The value of this inquiry will not be realized if you rely upon others for answers; you must obtain your answers by asking questions of nature. Since how you obtain your answer to your problem is more important than the answer you obtain, your report will be graded by the following points:

CRITERIA FOR THE EVALUATION OF THE "ORIGINAL" EXPERIMENT

1. Definition of the Problem
   a. Is the problem clearly defined and delimited?
   b. Can it be solved using scientific methods?
   c. Was problem "original" to you or did you know the answer before the experiment?
2. Design of the Experiment
   a. Did you select appropriate methods of collecting data?
   b. How well does the problem consider the availability of simple equipment and facilities?
   c. Does it have an adequate control?
   d. Is the variable clearly identified?
   e. Were provisions made to allow for the quantification of data?
3. Collection of Data
   a. Organization of data (graphs and charts)
   b. Was the data collected pertinent to the solution of the problem?
4. Interpretation
   a. Were conclusions based on data presented?
   b. Were the assumptions identified

upon which the conclusions were based?

5. Mechanics
   a. Is the report accurate, neat and complete to the extent that another person could verify the experiment?

QUESTIONS

1. What is an experimental control? When would you use a control? Why would you use a control?
2. Why does the atmosphere exert a pressure on the earth? What is this pressure when expressed in pounds per square inch?
3. Which is heavier, a cubic foot of hot air or a cubic foot of cold air? Why? Illustrate your answer by drawing a diagram of the molecules in a cubic foot of hot air and a cubic foot of cold air.
4. Draw a diagram of a mercury barometer and describe how it measures atmospheric pressure.
5. Make a list of the concepts required for a complete understanding of the results of Laboratory 12.
6. Describe the atmosphere in terms of oxygen and nitrogen. What proof do you have for your answer?
7. Briefly list how you would teach an elementary school science lesson to involve your pupils in a scientific inquiry. Include a short description of the so called "steps" of an inquiry.
8. What are the advantages and disadvantages of using a conceptual theme as a guide in teaching elementary science content?
9. Describe one of the new scientist-educator-designed elementary science programs. Describe briefly why you would or would not use this program in your teaching.
10. What are the laws of conservation of mass, matter, and volume and what considerations must be made in teaching these to pupils?

Further Investigation

1. Make a cartesian diver to illustrate air pressure. Fill a jar almost full with water. Fill a medicine dropper about half full with water. Place the medicine dropper inside the jar of water. It should float. If it sinks you have too much water in it. The purpose is to have the dropper floating straight up and down with the rubber part of the dropper just below the water level. Cut a balloon

of the test tube and the volume of the test tube up to the rubber band. This may be done with water and a graduated cylinder. Record this information in the form of percentages. Use this information to complete your inquiry. Include a complete description of your statement of the problem, hypotheses, procedure used, and a statement of your conclusion in your laboratory report.

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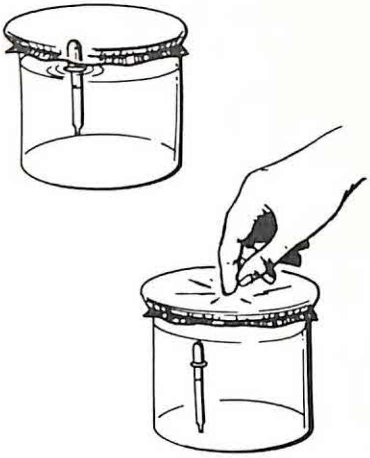
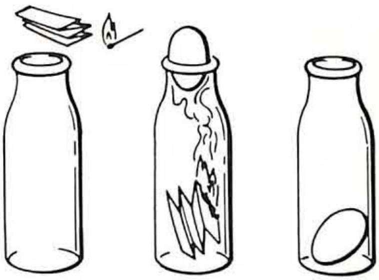
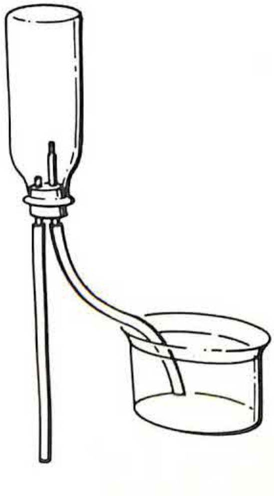
into a sheet and secure it over the mouth of the jar with a rubber band. Observe the amount of air in the medicine dropper as you press on the sheet of rubber and as you remove your hand. Describe what happens and what permits more water to enter the dropper, causing it to sink.



2. Put air pressure to work! Obtain a peeled, hard boiled egg and a glass milk bottle. Light a piece of paper, drop it into the bottle and immediately set the peeled egg onto the mouth of the bottle. Describe what happens and explain how you have put air pressure to work. Devise several methods to get the egg out of the bottle. Try each method.



3. Make a siphon fountain! Obtain two medicine droppers. Remove the rubber bulb. Obtain a 2-hole stopper to fit in a quart milk bottle. Place one glass tube, point in, through one hole leaving most of the glass tube on the inside of the bottle. Place the other glass tube, point out, through the other hole leaving most of the glass tube on the outside of the bottle. Obtain two pieces of rubber tubing, one about 25 centimeters long and the other about 75 centimeters long. Connect the long rubber tube to the glass tube with the point outside the bottle and the short rubber tube to the other glass tube. Fill a large glass jar with colored water. The long tube should drain down to a jar or bucket on the floor. Start the siphon by sucking on the long tube (floor level) until the water begins to flow. Describe the results in terms of gravity, a partial vacuum, and air pressure.



4. Place a glass tube through a one-hole stopper. Place the stopper in a flask of water. Push the stopper into the mouth of the flask. Try to drink through the straw as if it were a drinking straw. Now pull the stopper up out of the flask a short distance. Try again to drink through the straw. Explain what happens in terms of air pressure.
5. Make a siphon. Fill a jar almost full of water. Fill a piece of rubber tubing full of water. Place one end in the jar of water and the other end in an empty jar, which is lower than the jar of water. Explain what causes the water to move.

4

How Does Water Behave?

You have completed laboratory experiences dealing with concepts of the molecule and with concepts of air. The following lesson on water may contain concepts with which you are not thoroughly familiar. Perhaps this was true in previous laboratory experiences, also. How will you react when you are teaching science concepts with which you are not familiar?

One of the biggest factors that influence the attitudes of children is the behavior the children observe in their teachers and parents. Often the attitudes of a child are a reflection of their teacher's attitude.

Your education is not complete when you finish school. When you have completed your formal schooling, you will continue learning in a less formal way. One of the main purposes of your college work is to teach you how to learn when you complete your schooling. The objective of teaching is to make it possible for your pupils not to need a teacher. Everyone is continually learning as he works in his chosen profession. Even a scientist is continually learning as he seeks to understand nature. As the scientist learns, he sometimes makes mistakes. But he is honest about his mistakes and seeks to correct them. He will sometimes

work with other scientists, tossing ideas about in discussions aimed at gaining a clearer understanding of his work. He may then test some of these ideas through experimentation or observations.

These are some of the activities of a scientist. These are also some of the activities of a classroom—children work together in seeking to understand nature by discussing topics with the teacher and their classmates, then testing their ideas through experimentation or observation. Therefore, even though you may not know all of the science concepts (and you are really not expected to know everything), you will still be able to display a scientific attitude for your pupils to reflect. Take, for example, the attitude of honesty. There is nothing wrong with admitting that you are learning along with your pupils, or even that some of your pupils may be learning faster than you are. This procedure of honesty is necessary, for scientific procedures are procedures of honesty. Perhaps by exhibiting such behavior patterns you can help your pupils to develop scientific attitudes.

LABORATORY 14
MOLECULAR WATER

Individual molecules generally cannot be seen. But, if you could see molecules, what would you observe as you look at a drop of water? Let's imagine you have some kind of a super microscope permitting you to see molecules. Looking into this super microscope you see molecules of air darting about, bumping into each other and other objects, then rebounding only to bump into something else. Upon placing a drop of water under the super microscope you see that water, like all other substances, is composed of molecules. But, the molecules of water are not moving about as much as the air molecules; they seem to vibrate about while staying in a relatively smaller area. Notice also that some of the water molecules move faster than others and every now and then one begins to move so fast that it breaks away from the water to move about as air molecules do.

What would happen if you applied heat to the water? The molecules would start to vibrate faster. Finally, some of the molecules would vibrate fast enough to escape from the liquid state of water and go into the gaseous state. However, if you were to follow a few of these gaseous water molecules through the air, you would find that this process is constantly being reversed. The gaseous water molecules lose their heat energy (perhaps to a cold window pane surface) and move more slowly, slowing back to vibrating in a relatively small area. Moving more slowly, they may start clumping together to form water droplets (dew).

Water molecules are never standing still. They are constantly going from the liquid state to the gaseous state back to the liquid state. An understanding of these concepts is basic to many science lessons. For example, teaching and learning situations in a weather lesson will involve the water cycle—water going from the liquid state into gaseous state and back to the liquid state. Every child has experienced the weather and many senses are usually employed in his weather experiences. Teaching molecular concepts in a weather lesson can, therefore, have a very personal meaning for your pupils.

Problem:

What affects the movement of water molecules?

Materials:

Equipment	*Expendables*
Beaker	Alcohol
Burner	
Metric ruler	
Ring stand	
Iron ring	
Wire gauze	

Procedure:

1. Fill a beaker about one-fourth full with water. Record the depth of the water in centimeters. Place the beaker of water on a ring stand and place a lighted burner under the beaker. Observe as the water is heated. What observations can you make about water as it is heated? Let the water boil for several minutes. Record the depth of the water after it has cooled. In terms of molecules, what happened to the missing water? Where did the water molecules obtain sufficient energy to leave the liquid state? Where did the water molecules go?
2. Moisten two places on your laboratory table with a wet paper towel. The wet places should be about 25 centimeters or more apart. Fan one of the wet spots with a piece of paper for several minutes until you notice a change. Describe your observation in terms of water molecules. Why were *two* spots moistened?
3. Dampen both places with water again. Gently warm one wet spot with a burner flame. Describe your observations in terms of water molecules.
4. Place one drop of alcohol on the laboratory table. (Danger: Alcohol is flammable. Do not have any flames near the bottle of alcohol.) Place one drop of water 25 centimeters from the alcohol. Fan the alcohol drop with a piece of paper. Describe what happens in terms of alcohol molecules. Place one drop of alcohol on the back of your hand. Fan the alcohol with your other hand. What do you feel? Why? Where did the heat go? If heat is a manifestation of molecular movement, what proof do you have that some molecules move faster than others? Describe in some detail how evaporation cools. Make your description in terms of molecular movement. Include a diagram or series of diagrams with your description in the conclusion section of your laboratory report.

LABORATORY 15 OPPORTUNITY FOR INQUIRY: CONTROLLING WATER MOLECULES

Part A

Does the amount of surface area of water have any effect on the rate which molecules leave the liquid state? Does the temperature of the water have any effect on the rate which the molecules leave? Design an investigation to answer these questions. Include your hypotheses and a description of your investigation in the procedure section of

your laboratory report. Include any data tables and graphs, temperature readings, and other measurements in the data section of your report. State your conclusions (based upon your data, regardless if it agrees with your hypotheses or not) in clear, short sentences.

Part B

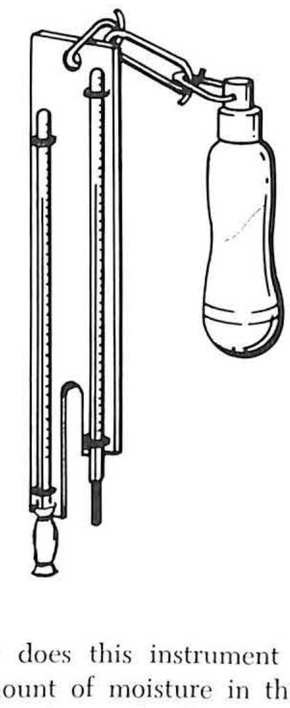
It was stated in the introduction that the process of evaporation can be reversed. How can you slow gaseous water molecules to cause them to return to the liquid state? Obtain some ice and a dry beaker. Place the ice in the beaker and add water. Be sure the outside of the beaker remains dry. Observe the outside of the beaker until you see a change. If you could keep the beaker cold, how long could you observe this occurrence? What is the basis for your answer? Many statements you make are based upon assumptions.

One reason that pupils sometimes have difficulty in understanding a demonstration is that the teacher fails to discuss the assumptions involved in reaching a conclusion. The answer may be obvious to her because she knows certain facts from which the conclusion is reached. But if a pupil does not know the assumptions, he may get the false impression that his teacher is the authority. Make it a practice to understand the underlying assumptions in your statements and attempt to have children identify them in discussions.

LABORATORY 16 WATER IN THE AIR

Introduction

How much water do you think is in the air? Weather observers measure the amount of water in the air with a type of instrument called a hygrometer. One type of hygrometer, called a sling psychrometer, is two thermometers attached to a frame enabling the observer to "sling" them around in the air. One of the thermometers with a cloth wick on the bulb end is called the "wet bulb" thermometer. The wick is moistened with water before the thermometers are whirled through the air. The other thermometer is called the "dry bulb" thermometer.



How does this instrument measure the amount of moisture in the air? If the air is dry, molecules of water will leave the wick. If the air is completely saturated with water molecules (relative humidity 100 per cent), fewer molecules of water will leave the wick. Of course, the air usually contains some amount of moisture between these two extremes.

The wet wick contains some water molecules that are moving faster than others. These faster-moving molecules will leave the wick before the slower-moving molecules. Temperature may be

defined as a measure of the average energy of motion that the molecules have. Because the fast-moving molecules have left the wick, the slower-moving molecules on the wick have less average energy of motion. Therefore, their temperature is lowered. The number of molecules leaving the wick will be greater than those returning to the wick until equilibrium is reached. At equilibrium, as many molecules of water vapor condense on the wick as evaporate from the wick every second. The temperature of the wet bulb thermometer at this point is the "wet bulb temperature."

If the air contains many water vapor molecules (nearly saturated), the equilibrium point will be reached rapidly. The wet bulb temperature will be only a few degrees cooler than the dry bulb temperature. If the air is very dry, the equilibrium point will be at a much lower temperature than the dry bulb temperature. Therefore, by comparing the temperature of the wet bulb with the actual temperature, you may determine how much moisture is in the air by using tables prepared for this purpose.

Problem:

How is the amount of moisture in the air measured?

Materials:

Equipment	*Expendables*
Sling psychrometer	Water

Procedure:

Obtain a sling psychrometer. Using the psychrometric table, determine: (a) the amount of moisture in your classroom (relative humidity), and (b) the relative humidity of the air outside the building.

DATA TABLE

	DRY BULB	WET BULB	DIFFERENCE	RELATIVE HUMIDITY
Classroom	______°F.	______°F.	______°F.	______%
Outside	______°F.	______°F.	______°F.	______%

PSYCHROMETRIC TABLE

Relative Humidity (%)

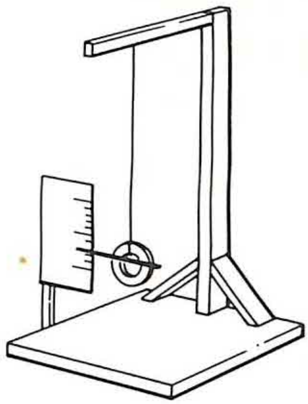
Air Temp. (°F.)	Depression of Wet-bulb Thermometer (°F.) (Dry bulb − Wet bulb = Depression of wet bulb)											
	1	2	3	4	6	8	10	12	14	16	18	20
0	67	33	1									
5	73	46	20									
10	78	56	34	13								
15	82	64	46	29								
20	85	70	55	40	12							
25	87	74	62	49	25	1						
30	89	78	67	56	36	16						
35	91	81	72	63	45	27	10					
40	92	83	75	68	52	37	22	7				
45	93	86	78	71	57	44	31	18	6			
50	93	87	80	74	61	49	38	27	16	5		
55	94	88	82	76	65	54	43	33	23	14	5	
60	94	39	83	78	68	58	48	39	30	21	13	5
65	95	90	85	80	70	61	52	44	35	27	20	12
70	95	90	86	81	72	64	55	48	40	33	25	19
75	96	91	86	82	74	66	58	51	44	37	30	24
80	96	91	87	83	75	68	61	54	47	41	35	29
85	96	92	88	84	76	70	63	56	50	44	38	32
90	96	92	89	85	78	71	65	58	52	47	41	36
95	96	93	89	86	79	72	66	60	54	49	44	38
100	96	93	89	86	80	73	68	62	56	51	46	41

QUESTIONS

1. Describe (a) evaporation, and (b) condensation in terms of water molecules.
2. When you are wet, such as just after stepping out of a swimming pool, you feel cool. Why is this? Why does evaporation produce cooling?
3. Why does a person's eye glasses become fogged when he walks into a warm room from the cold?
4. When the temperature is about 40°F. some people claim that they can "see" their breath when they exhale. What is it they actually see? What causes this?
5. What is heat? What is temperature? At an altitude of several hundred miles, the temperature may be in the thousands of degrees Fahrenheit, but a man would freeze in a matter of seconds. Explain this apparent paradox.
6. What is a scientific attitude? Describe how you would teach your pupils to exhibit a scientific attitude.
7. What is an assumption? Why is it important that you know when you are using assumptions in your teaching?

Further Investigation

1. Make a hair hygrometer. Obtain one long hair which has been cleaned with alcohol to remove the oil. Tie a small weight to one end of the hair and suspend the other end from some support. Place an upright scale next to the weight. As the humidity changes the hair will contract or stretch, thus causing the weight to go up or down. Calibrate the scale by comparing readings from a sling psychrometer with the position of the weight.



2. Test for water. Obtain some copper sulfate. Place the copper sulfate in a test tube and heat over a burner flame. What forms in the top of the test tube? When the copper sulfate becomes a light blue or whitish-blue color most of the water has been driven out. When water is added to it, the deep blue color returns. Test several substances to see if they contain water. You may wish to try different brands of gasoline, different brands of hair spray, or other commercial mixtures. Place a small amount of the light blue copper sulfate in the liquid.
3. Find the dew point. The dew point is the temperature at which the moisture in the air will begin to condense. Place several ice cubes in a beaker of water. Gently stir the ice and water with a thermometer as you watch the outside surface of the beaker for condensation to form. As soon as condensation forms, read the thermometer. This is the dew point. Will this tell you if dew or frost will form? Try this for several nights and see if you can make predictions. How can you use this temperature and the air temperature to determine the relative humidity?
4. Would you pay 60¢ a pound for water? It has been stated that fruits contain up to 80 per cent water and meats contain up to 50 per cent water. Design an experiment to find how much water is in different fruits or meats.
5. Demonstrate the cohesion between water molecules. Fill a water glass level full of water. Drop paper clips one at a time into the water glass. Do not jar or disturb the glass or water. How does this demonstrate the force of attraction between water molecules? Is this force a factor in keeping water molecules from leaving the liquid state?
6. Why does a steel ship float on water? Obtain a sheet of tin and a spring balance. Weigh the tin sheet. Place the sheet of tin on some water. Does it float? Attach the spring balance and weigh the tin sheet under water. Bend the sides of the sheet to form a tray, then set it on some water. Mark the position of the water line on the inside tray. Remove the tray from the water, fill the inside of the tray with water up to the marked water line. Weigh the water. What other weight does this weight of water equal? How much water did the tray displace when it was floating? What is buoyancy? How does a steel ship float on water?

5

Heat, the Energy of Molecules

What is science? Have you learned how a scientist works in the laboratory? Science is basically a means of understanding how things happen as they do. Science is a process by which your search for answers can be conducted systematically. Science, as a process of inquiry, stems from human needs and is guided by scientific attitudes. These attitudes are put to use with a number of intellectual and technological tools. You have used some of the basic technological tools, balances and microscopes, for example, in the laboratory. Have you used any intellectual tools?

In attempting to describe or explain a number of apparently related happenings, a scientist attempts to integrate the happenings into a pattern. This pattern is an attempt to relate a relatively large number of observations. The scientist uses the pattern in an attempt to predict future events, thus forming a framework for further investigations. These frameworks may be called theories.

Theories are tentative, as are many aspects of science. Throughout the history

of science, there are many records of misconceptions in the form of theories. One such theory is noted in the following laboratory. How will some of our present-day theories become doubtful in the future? Since this possibility exists, can you justify teaching theories that may be outdated when your pupils become adults? You should emphasize the development of scientific principles and methodology instead of the memorization of facts. If you employ the discovery approach in teaching science with the emphasis upon inductive learning, problem solving, and critical thinking, you will be preparing your pupils for the world in which they live.

LABORATORY 17 HEAT AND THE MOTION OF MOLECULES

Introduction

Have you ever returned to your car on a warm summer day to find gasoline overflowing from the tank? What caused this? Perhaps it was caused by the increase of temperature as the day became warmer. But how would a rise in temperature cause a gasoline tank to overflow? Until about 200 years ago people thought they had the answer to this and other questions related to heat. They thought that heat was a fluid. This fluid was called phlogiston. In this theory, something was hot because it contained phlogiston or cold because it lacked phlogiston. They would have explained that your gasoline tank overflowed because phlogiston flowed into it.

The phlogiston theory would say that your hands become warm if you hold them over a fire because phlogiston flows into your hands. "This is why," a phlogiston theorist would say, "you wear a coat—to hold in phlogiston." Here we see an example of a theory—a theory that was later shown to be a misconception. When a theory does not account for all observations, the theory is no longer valid. For example, how would the phlogiston theory explain why your hands become warm as you rub them together? "Phlogiston flowing into your hands," the phlogiston theorist would say. But, where is the phlogiston flowing from? Something must be getting cold as the phlogiston leaves. Since your arms and everything around your hands stay warm, then the theory does not explain where the heat came from. What is heat? Perhaps you will be able to formulate your own theory of heat after the following investigation.

Problem:

What is heat?

Materials:

Equipment
Test tube
Burner
Test tube holder
Thermometer

Expendables
Fine sand, 15 cc
Tape

Procedure:

1. Place 15 cubic centimeters of sand into a test tube. (Note: 1 cubic centimeter equals 1 milliliter.)

2. Place a thermometer into the sand. Observe the level of the liquid in the thermometer until you are sure the liquid is no longer changing. Record the temperature of the sand.
3. Cover the open end of the test tube with a piece of paper. Seal the paper over the test tube with tape. Shake the sand vigorously for at least three minutes, then quickly insert the thermometer into the sand. When you are sure the level of the liquid in the thermometer is no longer changing, record the temperature. Record the difference in temperature of the sand before and after in terms of molecules of the sand particles.
4. Again record the temperature of the sand and remove the thermometer from the test tube. Place the test tube in a holder and heat the sand over a burner flame for about 5 seconds. Play the flame over all parts of the test tube. Quickly insert the thermometer into the sand and record its temperature. (*CAUTION:* Do not overheat the thermometer!) Record the difference in temperature of the sand before and after it was held over the flame. In terms of sand molecules, what caused this change? If you were handed two test tubes, each containing warm sand of the same temperature, could you tell what warmed each? In terms of molecules, what is heat?

CHANGE IN TEMPERATURE

	Before	After	Difference
Sand (shaken)	______ F.	______ F.	______ F.
Sand (burner)	______ F.	______ F.	______ F.

LABORATORY 18
MOVING MOLECULES

Introduction

A theory is devised to explain a large number of related happenings. In explaining these, a theory should also be able to predict related events. Theories are tentative, and when a theory fails to predict accurately, the theory is no longer valid.

In the last laboratory you formulated a theory. You made a simple statement in an attempt to relate your observations of the investigation. Let's put your theory to the test. Will your theory of heat predict what will happen when heat is added to a solid? To a liquid? To a gas? What do you predict will happen? What relationship exists, if any, between the three states of matter according to your theory? Record your predictions before going into the laboratory.

Problem:

What is the effect of temperature on a solid, liquid, and gas?

Materials:

Equipment
Flask

Expendables
Food coloring or ink

Beaker
Stopper, 1-hole
Glass tube
Burner
Wire, 50 cm. copper
Ring stand
Meter stick
Iron ring
Wire gauze

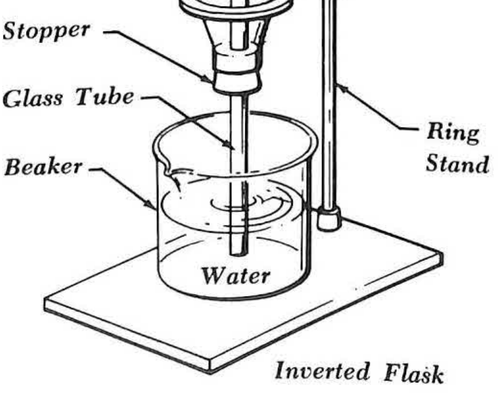
Procedure:

Part A

1. Obtain a 15-centimeter length of glass tubing. Insert the tube about three centimeters through a one-hole stopper. (*CAUTION:* Observe the precautions of working with glass tubing. Protect your hands!)
2. Fill a flask level full with cold, colored water. Push the stopper into the flask.
3. Mark the level of water in the glass tube. The level should be between one-third and one-half the length of the tube.
4. Heat the flask on a ring stand over a burner. Record your observations. Did your theory of heat predict your observations? What conservation laws are involved in this activity?

Part B

1. Pour the colored water out of the flask and into a beaker. Rinse the flask with cold water. Replace the stopper containing the glass tube.
2. Invert the flask and place it in the iron ring on the ring stand. Put the beaker of water under the flask and lower the flask until the tube is under water.



Inverted Flask

3. Gently heat the flask by moving a burner flame across the upper part of the flask until five or six bubbles escape from the tube. Of what are the bubbles made? Record your observations both as the flask is heated and as it cools. Did your theory of heat predict your observations? What other factor was involved to produce the observed results as the flask cooled?

Part C

1. Obtain a 50-centimeter length of copper wire. Tie one end of the wire to an iron ring on a ring stand. Tie a weight to the free end. Adjust the ring until the weight is five centimeters above the ring stand base.
2. Heat the length of the wire by moving a burner flame along it.
3. While the wire is hot, measure the distance between the weight and the ring base. Record any change. Does your theory of heat predict your observations? Record your theory of heat as your hypothesis in your laboratory report. Indicate in your conclusion how your data supports your conclusion.
4. What conservation principles are involved in this activity?

LABORATORY 19
OPPORTUNITY FOR INQUIRY: MEASURING MOLECULAR MOTION

Have you ever had your hands in snow, or in very cold water and then placed them in cold water? The water feels warm! Have you ever been in complete disagreement as to the temperature of a room—one person says it is warm while you feel that it is cool?

How would you start if you were constructing the first thermometer? Fahrenheit's thermometer was a mercury-filled tube. Fahrenheit may not have realized that heat is the energy of motion of molecules, nor that warming mercury caused the molecules of mercury to move faster and occupy more space. He did know, however, that heat caused mercury to expand and cold caused it to contract—so the level of mercury in his thermometer would rise when it became hot and fall when it became cold. But how hot and how cold? This thermometer would tell only if the temperature were hot or cold. Fahrenheit designed a scale so his thermometer would register specific temperatures. He placed two fixed points on the scale and divided the distance between the points into degrees. The upper fixed point was placed at the boiling point of water at sea level and the lower fixed point at the freezing point of salt water. The space between these two fixed points was divided into 212 equal degrees. This places the boiling point of water at sea level at 212° and the freezing point of water 32° (and the freezing point of salt water at 0°) on the Fahrenheit thermometer.

Years later, in 1725, Anders Celsius modified Fahrenheit's thermometer. Celsius placed the fixed points at the freezing point of water and the boiling point at sea level. He divided the space between these two fixed points into 100 equal degrees. Thus, from the metric system, Celsius' thermometer is sometimes called the *centi*grade thermometer.

In the last laboratory you observed that temperature affects solids, liquids, and gases. Review your data and determine which of the three would make the best thermometer. Explain why you

chose it. Using the equipment from the latest laboratory, construct a thermometer. Determine two fixed points (not necessarily the freezing or boiling point of water). Divide the space between the two fixed points into degrees. Compare your thermometer with those of your classmates. Include a complete description of your thermometer in your laboratory report and give reasons why you picked the fixed points and degree interval on your thermometer. Make a drawing to show the relationship between a Celsius thermometer, a Fahrenheit thermometer, and your thermometer. Draw a scale of each, side by side, and include it in your laboratory report.

QUESTIONS

1. What is heat?
2. A tub of cold water contains more heat than a red-hot pin, but the pin has a higher temperature than the tub of water. Define heat and temperature from a molecular viewpoint.
3. When a liquid is heated, it increases in volume. Where does this "extra" liquid come from? Why does matter expand as it is heated?
4. Why is mercury or alcohol used in a thermometer instead of water?
5. What is the lowest temperature a substance will ever reach? What thermometer scale is used to measure temperatures this cold?
6. What is the size relationship between the Fahrenheit degree and the Celsius degree?
7. Should you employ the discovery approach in teaching science rather than the lecture approach of teaching scientific facts? Why or why not? What, if anything, is wrong about teaching science facts as ends in themselves?
8. What is scientific theory? What are the criteria for a valid theory? Of what use is a scientific theory?

Further Investigation

1. Pound a nail with a hammer. Touch the nail. Why does it become hot?
2. Bend a piece of wire back and forth until it breaks. Touch the end of the wire at the break. Why is it hot?
3. Obtain a thin copper strip and a thin iron strip about 5 centimeters wide and 25 centimeters long. Place the two strips together and drill or punch holes about five centimeters apart. Using small screws and bolts, bind the two strips together tightly. Place one end of the bimetallic strip in a flame; then place it in cold water. What does this pair of metal strips do when it is heated? How could this be used to make a thermostat?
4. Obtain a length of copper wire and an iron wire of the same size. Twist the wires together at one end. Connect the free ends to a galvanometer. Heat the twisted ends of the wires in a burner flame. What happens to the needle on the galvanometer? How could this be used as a thermometer?
5. Produce a temperature of $-100°$F. Crush some dry ice, place it in a container and pour acetone over the dry ice until no more dry ice dissolves in the acetone. Find what effect extreme cold has on liquid mercury, rubber bands, blown up balloons, flowers, and various fruits. Be sure to wear gloves and keep hands out of the mixture.

6

What is Sound?

There is no substitute for the active involvement of children in performing science experiments. An elementary teacher who only talks about science or just has children read fails to provide opportunities for lasting learning. A philosopher said about 2,000 years ago, a dry class will result in mentally stunted pupils just as dry soil will produce stunted plants.

Learning by doing is perhaps a well-accepted principle among teachers. Science, especially, lends itself to learning by doing. Why do not more teachers practice this principle? Many say, "We have no facilities for such teaching! We only have a classroom, desks, chairs, and the usual audio-visual equipment." This is a rather limited view of a classroom. Should learning be bound by four walls? Science teaching demands flexibility and innovations with available equipment. There are many materials adaptable to science teaching outside the classroom, both within the school building and in the community. Science classes should make use of common, everyday materials as well as resources outside the room in which science is taught. Your science classroom should know no boundaries; your science class should help pupils to see that science is all around them.

Another common mistake that some teachers in the "bounded-by-four walls"

classroom make is that science can be studied only with apparatus and supplies purchased from scientific supply companies. These commercial materials may be desirable, but in many cases can be substituted with ordinary materials. This should not imply that an elementary teacher should not purchase equipment. However, commercial materials remove experiences from the real world of the pupil. Whenever possible, materials and apparatus should be constructed from materials familiar to children. Conducting science lessons in the pupils' own environment demands that much of the materials and apparatus used must be improvised. Do not avoid experiments with beakers when water glasses (or even paper cups) will serve as water containers. Review several professional teaching journals for ideas. What innovations and equipment are used in *Science and Children* articles? Other publications helpful to the elementary teacher in outlining science experiences and making innovations of laboratory equipment are: *The UNESCO Source Book for Science Teaching* (UNESCO Publications Center, New York) and *Teaching Elementary Science: A Source Book for Elementary Science* (Harcourt Brace and World, Inc., New York). The book review column of such journals as *The Science Teacher, Science Education, Journal of Research in Science Teaching, Science,* and *School Science and Mathematics* provide information on recent books that may be of help to the science teacher.

LABORATORY 20
PUSHING AND PULLING MOLECULES

Introduction

What would you answer if a fifth grade pupil asks you, "If a tree falls in the forest and there were no one around to hear it, would there be a sound?" This age-old question could provide your pupils with an opportunity to initiate an inquiry and to express their ideas. Children should have an opportunity to express themselves without fear of ridicule. Do not criticize their ideas even if you think they are incomplete or inaccurate. If a misconception does arise, how will you react? There is an old proverb which says, "If I hear, I forget; if I see, I remember; if I do, I know!" Therefore, it is better not to correct a child's misconceptions immediately, but to provide situations so he will correct himself. You are interested in creating the possibilities for your pupils to create and invent, and to become active in learning for themselves. Now, to return to your fifth grader's question—if a tree falls in the forest . . . will there be a sound?

Part A

Problem:

What is sound?

Materials:

Equipment
Tuning fork
Rubber band

Expendables
None

Beaker
Match box, empty

Procedure:

1. Place a rubber band around a small box with the lid or cover removed. Pluck the rubber band. What do you hear? Describe the motions of the rubber band.
2. Strike a tuning fork with a rubber hammer or strike it against your knee-cap. Hold the vibrating tuning fork next to your ear. Describe what you hear. Again strike the tuning fork. Quickly dip the prongs into a container of water. Record your observations. Again strike the tuning fork. Touch the prongs to a sheet of paper held in your hand. Record your observations. From your observations, describe the motion of the tuning fork prongs. What is the source of the sound from a plucked rubber band and from a tuning fork that has been hit with a rubber hammer?
3. Obtain an alarm clock. Wind the clock and set it to ring in five minutes. Place the clock on the stage of a vacuum pump and cover it with a bell jar. Exhaust the air from the bell jar. When the alarm starts ringing, allow air to enter the jar. Record your observations. What is necessary for sound to travel from the source to you?
4. Fill a sink or a large container full of water. When the surface is still, drop a small object into the water. Describe the disturbance on the water.
5. Obtain 8 or 10 marbles. Place the marbles on the chalk tray of the chalk board. Place all of the marbles side by side except one. Roll the free marble against the end of the row of marbles. Repeat this procedure several times, making sure that all marbles in the row are touching each other. Vary the procedure by rolling 2, then 3 marbles into the row. Record your observations. How can sound waves travel across a room? Do air molecules stay in the same place or do they move across the room? How can you investigate this?
6. Summarize your observations. Considering the motion of a plucked rubber band, a vibrating tuning fork, and the molecular nature of air, answer the following questions:
   (a) What causes sound?
   (b) How does sound get from a tuning fork to your ear?

Part B

Problem:

Does sound travel through different states of matter at the same speed?

Materials:

Equipment
Water container, large
Rocks, 2 small
Meter stick
Tuning fork

Expendables
None

Procedure:

1. You have investigated how air carries sound waves. Now compare sound waves in air with sound waves in other materials. Fill a container with water. Strike two objects (such as two rocks) together both in the air and under water. When the objects are struck together under water, your partner should hold his ear next to the container of water. Which sound is louder? Does sound travel better through water or through air?
2. Stand about one meter from your laboratory partner. Strike the prongs of a tuning fork. Compare the loudness of the tone through air with the loudness of the tone through a solid by the following method. As your partner holds one end of a meter stick to his ear, touch the stem of the tuning fork to the other end of the meter stick. Repeat this procedure as he holds the end of the meter stick against his front teeth. Exchange roles and repeat the procedure. Which tone was louder? Does sound travel best through solids or through air?
3. Compare your observations from Part A, steps 4 and 5 and from Part B, steps 1 and 2. Try to answer the following question: Why does sound travel through solids and liquids better than through air? (Hint: Consider the solid, liquid, and air from a molecular viewpoint! Perhaps you will wish to repeat the procedure in step 5.)

LABORATORY 21
THE SPEED OF SOUND

Introduction

You may not have thought about it at the time, but you have seen examples that sound travels at a measurable speed. Perhaps you wondered at seeing a worker (at some distance) hammering a board, only to hear the hammer strike the board out of sequence with what you see. Light travels at such a tremendous speed that it can travel thousands of miles in the same time required for you to blink your eyes. For all practical purposes, light can be considered to be instantaneous; you can say that you see something at the same time it happens. Sound, however, travels at a much slower speed. Thus, you see the worker strike a board with his hammer at the instant he does so, but you hear the sound a moment later.

Lightning and thunder offer another example that sound travels at a measurable speed. Lightning may be seen as much as a half minute before the thunder is heard. Because of this difference some people do not realize that the two events occur at the same time; the lightning actually causes the thunder. If you consider that lightning happens when you see it and you time the interval until you hear the thunder, it is possible to compute the distance from you to the place where the lightning occurred. For example, if it takes sound 5 seconds to travel one mile, and if the time interval between the lightning and thunder was 5 seconds, the lightning occurred one mile away.

If a car travels 60 miles per hour, it covers a distance of one mile. How long would it take a sound to travel the same distance?

Problem:

What is the speed of sound?

Materials:

Equipment
Loud bell, gong, or whistle
Stop watch

Expendables
None

Procedure:

This determination of the speed of sound is to be performed in a large, open field. It is suggested that you work in groups of eight, with four at one end of the measured distance and four at the other end.

1. Measure accurately the distance between two points in an open field. The distance should be at least 800 feet, but the longer the distance through which the sound can be heard, the better the results will be.
2. A group of four will be at one end of the measured distance and the other group will be at the other end. One group will make a sound with a loud bell, gong, or whistle. Determine some method of making a visual signal to correspond with the beginning of the sound. The other group must begin the stop watch when they see the visual signal and stop when they hear the sound.
3. Repeat the procedure until you get fairly consistent results. Include the distance, time for the sound to travel this distance, your computed speed of sound in feet per second, and the actual speed of sound in feet per second. Be sure to include the data from every trial.

Alternate Procedure:

If you live in the vicinity of a cliff or a high wall that produces an echo, you can conduct this investigation individually.

SAMPLE DATA TABLE

		_____ feet	_____ feet	_____ feet	_____ feet	_____ feet
Trial	1	_____ sec.	_____ sec.	_____ sec.	_____ sec.	_____ sec.
	2	_____ sec.	_____ sec.	_____ sec.	_____ sec.	_____ sec.
	3	_____ sec.	_____ sec.	_____ sec.	_____ sec.	_____ sec.
	4	_____ sec.	_____ sec.	_____ sec.	_____ sec.	_____ sec.
	5	_____ sec.	_____ sec.	_____ sec.	_____ sec.	_____ sec.
	6	_____ sec.	_____ sec.	_____ sec.	_____ sec.	_____ sec.
	7	_____ sec.	_____ sec.	_____ sec.	_____ sec.	_____ sec.
	8	_____ sec.	_____ sec.	_____ sec.	_____ sec.	_____ sec.
Average		_____ sec.	_____ sec.	_____ sec.	_____ sec.	_____ sec.

Computed speed of sound _________ feet/sec.
Actual speed of sound _________ feet/sec.

After measuring the distance to the cliff and back to where you will stand, make a loud noise as you begin the stop watch. When you hear the echo, stop the watch. You have measured the time for the sound to travel to the cliff and back. Compute the speed of sound in feet per second.

QUESTIONS

1. What causes sound? Give an example.
2. How does sound travel? Answer from the molecular viewpoint.
3. Explain why sound does not travel through a vacuum.
4. Why do some materials carry sounds better than other materials? Answer from the molecular viewpoint.
5. Listen for five minutes. See how many different sounds you can record. After five minutes, tell what did the vibrating to produce the first seven sounds on your list.
6. Sound travels faster in air at 70°F. than it does in air at 32°F. From your knowledge of how sound travels through air, explain from the molecular viewpoint why sound travels faster in warm air than in cold air.
7. (a) What is the speed of sound in feet per second?
   (b) Consider sound to travel 1 mile in 5 seconds. If you hear thunder 8 seconds after you see a lightning flash, how far away was the lightning bolt?
8. (a) What reasons do some elementary teachers give for not involving their pupils in science experiments?
   (b) Are they justified in their reasons? Why?
9. Discuss one science experiment from a *Science and Children* article. Comment on the facilities and apparatus required for the activity. Would a typical elementary teacher have difficulty with the lesson?
10. Why is it generally wrong to tell a pupil that he is wrong in his answers, and then tell him the correct answers?
11. What sources will you consult when you need help with science? List five or more resources which the elementary teacher can utilize.
12. (a) Which is more important in a laboratory activity, to verify principles or form generalizations? Why?
    (b) Which is more important in evaluation, for your pupils to quote principles or apply generalizations? Why? What are some problems in making generalizations in science?
13. Teaching science as a discovery process requires much more time than teaching science as a body of knowledge. Are you justified in using the discovery process, even though you may not cover as much science? Should all science be taught by discovery? Give reasons for your answer.
14. In some classrooms, the "authority" for science is the teacher. In other classrooms, the text is the "authority" and in still other classrooms nature is the "authority." How would traditional instruction change if nature is accepted as the authority for learning? Is this important? Why?

Further Investigation

1. Investigate sound waves! Attach a broom straw to one prong of a tuning fork. Attach the handle of the tuning fork to a block of wood with tape. Smoke a small sheet of glass by holding it over a candle flame and moving it across the flame slowly. Place the tuning fork so the broom straw just touches the layer of soot on the glass. Vibrate the tuning fork prong. As it vibrates, pull the smoked glass under the broom straw. Repeat, using tuning forks of different frequencies.
2. Make a musical instrument from a soda straw. Obtain a paper soda straw. Flatten one end and cut the corners off the flat end. Place the flattened end into your mouth and blow. You may have to moisten the straw before you produce a sound. Vary the length of the soda straws to produce a different musical note with each straw. Set up an orchestra by giving a straw (one for each note) to a number of people. With each person responsible for a note, try to play some tune.
3. Make a "tin-can telephone." Obtain two empty tin cans with the lids smoothly cut out. Punch a small hole in the center of the bottom of each can. Thread 2 or 3 yards of thin thread through the holes and tie a match stick at each end so the string will not come out of the can. Stretch the string tight and use one can to talk into and the other to listen. Explain how sound travels from one can to another. Does this work on the same principle as your telephone at home?
4. Obtain an empty match box and a phonograph needle. Push the needle partly through one end of the box. Set a phonograph record in motion and place the needle into the groove. What do you hear? What do you feel in the match box? How does a phonograph record reproduce sounds?
5. See sound vibrations. Obtain an empty tin can with both ends smoothly cut out. Stretch a rubber sheet over one end and secure it with a rubber band. Glue a small piece of mirror, reflecting surface out, on the rubber sheet. Place it off-center a small distance. Shine a flashlight on the mirror so the light is reflected onto a chalk board. Make a sound near the open end of the can. Produce different notes near the open end of the can. What does this show about sound?

7

How Does Man Learn about Light?

Science has been defined as a process of inquiry, the art of understanding nature, a search for answers, and an attempt to explain why things happen. Is this all there is to science? Science in some textbooks is presented as a vocabulary study. It is sometimes taught with the emphasis on memorizing facts. Science does have an organized body of knowledge, including a number of facts. These facts have been accumulated by scientists as an outgrowth of their studies of nature. Textbooks usually organize these facts into subject-matter fields, such as biology, physics, chemistry, and astronomy. What the textbooks may not say is that this organized and systematized subject matter is only a product of science. A study of this body of knowledge is associated with an operation. A student equipped with only vocabulary will be poorly prepared to understand the world around him, which is dominated by science and technology.

How will you teach science? As a search for answers? As an attitude of inquiry? As a process? If so, how will your pupils acquire a basic background of science

needed for reasoning and even common sense problems? After all, no one can think without knowledge of facts.

Will you teach science as a body of knowledge, requesting that your students memorize facts? If so, how will your pupils learn an attitude of inquiry? How will they learn to cope with their environment as old ideas and concepts change? How will they understand the nature of science?

Science, as taught in schools, frequently is presented in a dogmatic form; as a body of knowledge. When science is presented only as a body of knowledge, your pupils do not gain an understanding of the nature of science. They also identify theories and concepts as facts. Theories are not necessarily descriptions of reality. For example, you may have heard that "matter is composed of atoms with three sub-atomic particles." Later, you may have learned that "atoms are composed of 30 or more sub-atomic particles." Did the "facts" change? No, a theory changed as new evidence became available. To understand science, it is important to distinguish between ideas expressed as facts ("water freezes at 32°F.") and ideas expressed as concepts ("water molecules move faster when heated").

Concepts (as the one about "water molecules moving faster when heated") may be part of a larger theory. In this case, the theory is that "all matter is composed of molecules." When such a theory is first formulated, it may take the form of a large hypothesis. From this large hypothesis scientists can deduce consequences that can be tested by experiment. Experimental science is an activity of testing hypotheses about a theory to increase the adequacy of the scheme. For example, a scientist may think, "If all matter is composed of molecules, then how are the molecules of water different from molecules of ice?" He then has a problem to which he can seek an answer through inquiry. In doing so, he may be testing the original theory.

How are theories, concepts, and facts derived? Perhaps you will find the answer to this question in the following fable from *Chemistry, An Experimental Science*,[1] the text of one of the new high school science projects (CHEM):

> Once upon a time a small child became lost. Because the weather was cold, he decided to gather materials for a fire. As he brought objects back to his campfire, he discovered that some of them burned and some of them didn't burn. To avoid collecting useless substances, the child began to keep track of those objects that burned and those that did not. (He organized his information.) After a few trips, his classification contained the information that is shown in the Table.

FLAMMABILITY

Will Burn	*Will Not Burn*
Tree limbs	Rocks
Broom handles	Blackberries
Pencils	Marbles
Chair legs	Paperweights
Flagpoles	

> This organization of the information was quite an aid in his quest for warmth. However, as tree limbs and broom handles are scarce, the child tried to find a regularity that would guide him to new burnable materials. Looking at the pile of objects that failed to burn and comparing it with the pile of objects that would burn, the child noticed that a regularity appeared. He proposed a possible "generalization."

[1]George C. Pimentel, *Chemistry, An Experimental Science*. San Francisco: W. H. Freeman & Company, 1960, pp. 3-4.

Perhaps: "Cylindrical
objects burn."

This procedure is one of the elementary logical thought processes by which information is systematized. It is called inductive reasoning and means that a general rule is framed on the basis of a collection of individual observations (or "facts"). Of what use is the inductive process? It is an efficient way of remembering.

The next day the child went looking for burnable materials, but he forgot to bring along his list. However, he remembered his generalization. So, he returned to his hearthside hauling a tree limb, an old cane, and three baseball bats (successful predictions!). What's more, he reflected with pleasure that he hadn't bothered to carry back some other objects: an automobile radiator, a piece of chain, and a large door. Since these objects weren't cylindrical, there was no reason to expect them to burn.

No doubt you are ready to complain that this generalization isn't really true! Quite the opposite! The generalization states a regularity discovered among all the observations available, and as long as observations are restricted to objects in the list, the generalization is applicable. A generalization is reliable within the bounds defined by the experiments that led to the rule. As long as we restrict ourselves to the objects in the table (together with canes and baseball bats), it is surely true that all of the cylindrical objects burn!

Because of his successful predictions, the child became confident of his generalization. The next day he deliberately left the list at his campsite. This time, with the aid of his rule, he came back heavily laden with three pieces of pipe, two ginger ale bottles, and the axle from an old car, while spurning a huge cardboard box full of newspapers.

During the long cold night that followed he drew these conclusions:

(1) The cylindrical shape of a burnable object may not be intimately associated with its flammability after all.

(2) Even though the "cylindrical" rule is no longer useful, tree limbs, broom handles, pencils, and the other burnables in the table still burn.

(3) He'd better bring his list along tomorrow.

But, thinking over the longer list, he saw a new regularity that fitted the table as the newly acquired information as well:

Perhaps: "Wooden
objects burn."

What good is this rule in the light of the earlier disappointment? Well, it caused the child to go back and get that door he had passed up two days earlier, but it didn't lead him to go after the chain, the automobile radiator, or the cardboard box full of newspapers.

Don't think this is facetious—it is exactly what science is all about! We make some observations, organize them, and seek regularities to aid us in the effective use of our knowledge. The regularities are stated as generalizations that are called theories. A theory is retained as long as it is consistent with the known facts of nature or as long as it is an aid in systematizing our knowledge. We can be sure that some day a number of our present scientific views will seem as absurd as "cylindrical objects burn." But on that day we will be proud of better views that have been substituted. If you are discouraged by the child's

> faltering progress—he hasn't yet decided that the box of newspapers will burn—be reassured. This child is a scientist and his faltering steps will lead him to the newspapers. They are the same steps that led up to our present understanding of relativity, to our discovery of polio vaccine, and to our propulsion of rockets to the moon.

From this fable, do you get the idea that scientific knowledge is not composed of unalterable, fixed truths? Is science knowledge, in reality, an incomplete, temporary, continuously restructured form of data and hypotheses? You can see that, even though a theory as "cylindrical objects burn" may be replaced later with a better theory, it may represent the extent of our present knowledge. Would there be any harm in teaching such a theory as a scientific fact to your pupils? How should it be taught?

Are theories replaced in science as they were in the fable? Conant, in his book *On Understanding Science*,[1] says,

> "We can put it down as one of the principles learned from the history of science that a theory is only overthrown by a better theory, never by contradictory facts. Attempts are first made to reconcile the contradictory facts to the existing conceptual scheme by some modification of the concept. Only the combination of a new concept with facts contradictory to the old ideas finally brings about a scientific revolution. When once this has taken place, then in only a few short years discovery follows discovery and the branch of science in question progresses by leaps and bounds."

[1]James B. Conant, *On Understanding Science*. New York: Mentor Books, 1951, p. 48.

If you are teaching theories as facts, how are your pupils (as adults) going to react when it is replaced by new theories? Will it help or hinder them in accepting change and new ideas?

That the body of knowledge called science is composed of highly provisional theories and explanations is very well illustrated by a study of light, for there are two different theories that appear to explain the behavior of light. One theory explains light in terms of wave motion, but another theory (called the corpuscular theory) explains light in terms of a stream of minute particles. Both theories seem to accommodate most of the known properties of light, but the corpuscular theory is the "better" one when light is falling on matter and the wave-motion theory is the "better" one to describe light traveling through space. Both are partial schemes appropriate to different conditions. But when light shows properties that fit the corpuscular theory, its properties that fit the wave-motion scheme tend to disappear, and vice versa. From this, some have concluded that precise knowledge of science is impossible and that perhaps there is not uniformity in nature after all. What does all of this mean to you, as an elementary school science teacher? Are you wondering which theory is correct? Which one should be taught as the truth? If you are, you have missed the point; both may be true representatives of reality, as they both are consistent with the known facts. Theories are not facts and should not be taught as such. As a teacher of science, how will you present theories? Can you teach skepticism through a dogmatic presentation? How can you teach the attitude of suspended judgment to your pupils? What advantages are derived from using theories as conceptual schemes for development of a curriculum framework? Investigate several of the new elementary science

projects. How do curriculums built around a conceptual scheme help pupils make their own entity of what would otherwise be just a collection of facts?

LABORATORY 22
THE NATURE OF LIGHT

Introduction

You use your five senses when observing the world around you. Which sense tells you the most about your surroundings? If you close your eyes for several minutes, you will agree that your eyes tell you more about your surroundings than any other sense. But you can see nothing if light is not present. Without light your eyes would be useless.

Why is the sky blue? What makes a rainbow? Why is the grass green? Why do I see myself in a mirror? These are questions your future pupils will ask you. These are also questions that Sir Isaac Newton asked. Newton conducted a series of experiments with light after he had wondered about a rainbow. He placed a triangular prism in the path of a beam of sunlight. The light coming out of the prism was not like the light going into the prism. Further experimentation caused Newton to conclude that white light is composed of many colors. His conclusion has been verified many times.

Much time and effort is saved in science by relying on the careful observations of others. It is sometimes necessary to rely on others' observations for, even if you wanted to, you could not repeat all the experiments about which you read and hear. It would take several lifetimes to check the validity of every experiment you read about. Scientists rely on each other's observations because they use accurate instruments, describe the exact conditions of the experiment, and can rely on each other's scientific integrity. This is why accurate reporting of experimental results is so important; scientists truly "stand on the shoulders of those who have worked before them." Scientists sometimes repeat the work of others to verify the conclusions, especially if they have some reason to doubt the results. Experiments of great scientists are sometimes repeated in schools with the hope that pupils will acquire some insight into science by verifying or repeating the scientist's work. Is this a valid and efficient teaching method? What objectives can be reached with this method? What objectives cannot be reached through this method? What are the pros and cons of teaching science by pupil verification of past experiments. You will verify Newton's experiment (from which he concluded that white light is composed of many colors) in Part B of this laboratory.

Problem:

What is the nature of light?

Materials:

Equipment
Prisms, 2
Knife (or razor blade)
Diffraction Grating (Edmund Scientific Co.)

Expendables
Construction paper, black

Procedure:

Work in teams of four or as directed by the instructor.

Part A

1. Cut a narrow slit, about 2 millimeters wide and 20 millimeters long, in the center of a sheet of heavy black construction paper.
2. Hold the paper up to the sunlight. Describe the way the light comes through the slit and forms a bright spot on the floor or wall. How large is the image compared to the slit? In what direction is it from the slit?
3. Pass the light from the slit through a small, triangular glass prism. What do you observe? Note carefully the position and orientation of the prism. Is the base upward or the apex upward? Record the order of the colors produced. Is red or violet bent more when the light goes through the prism? Make a sketch showing how the light rays may be going through the prism.
4. Hold the prism in front of your eyes and view the light coming through the slit. What is the order of colors now? How does the order compare with what you saw in procedure 3 of this laboratory? What is the explanation?

Part B

1. Fasten or hold the paper in sunlight so a beam of sunlight will pass through the slit in the center of the paper. Hold a prism in the beam of sunlight coming through the paper. Your laboratory partner will hold a sheet of paper in the beam of light coming from the prism. The sheet of paper is a screen for the light to fall on. Move the prism until a spectrum of color is on the screen.
2. Cut a slit in the sheet of paper you are using as a screen. The slit should be large enough to let only the blue light of the spectrum through.
3. A third partner will hold a second prism in the beam of blue light, and a fourth partner will hold a sheet of paper in the beam of light coming through the second prism. What color is the blue light after passing through a second prism?
4. Move the second sheet of paper with a slit in the center until only red light falls on the second prism. What color does the red light become after passing through a second prism?
5. Repeat this procedure with the green, yellow, orange, and violet light. What are the results when you attempt to break each color into other colors with the second prism?
6. Again, fasten or hold the paper in sunlight, so a beam of sunlight will pass through the slit in the center of the paper. Hold a prism in the beam of sunlight coming through the slit in the paper. A laboratory partner will hold a second prism in the spectrum coming from the first prism. The *complete spectrum* of colors must fall on the second prism. Another laboratory partner will hold a sheet of paper in the beam of light coming through the second prism. The sheet of paper will serve as a screen for the light coming through the

second prism. What happens to the colors in the spectrum when they pass through a second prism?

Part C
(Optional)

1. Obtain a small piece of plastic replica diffraction grating (transmission type). Hold the slit in the paper vertically in the sunlight and view the light through the diffraction grating. Do you see a spectrum of colors? How many spectra do you see? Describe the order of colors observed in each spectrum. Which colors appear to bend the most when light passes through a diffraction grating? How does this compare with light passing through a prism? Draw a sketch of the way the light rays may be going through the diffraction grating. Is diffraction the same as refraction? Find out about these two phenomena by doing some research in a physics book or in an encyclopedia. Which theory, wave motion or corpuscular, contains an explanation of why a prism causes light to form a spectrum?

LABORATORY 23
BEYOND THE VISIBLE SPECTRUM

Introduction

If you stand close to a fire, you will feel something that is emitted from the flame, although the flame does not touch you. You feel a similar warmth from the sun. In both cases, you are being exposed to a form of electromagnetic radiation. This radiation is similar to visible light, but longer in wave length; it is invisible to your eyes.

If one of your future pupils were to ask you why sunlight feels warm, how would you teach him the concept? Telling him that invisible radiation warms him will have little meaning. How can you associate such a concept with an experiment or demonstration?

Problem:

Do electromagnetic waves exist beyond the visible spectrum?

Materials:

Equipment
Prism
Thermometer (high range)

Expendables
Construction paper, black (from Laboratory 22)
Paint, black, flat, washable

Procedure:

1. Paint the bulb of a thermometer with black "tempera" or similar washable black paint.
2. While the paint on the thermometer bulb is drying, cut a narrow slit about 2

millimeters wide and 20 millimeters long in the center of a sheet of black construction paper (or use paper with slit from Laboratory 22).

3. Fasten or hold the paper in sunlight, so a narrow beam of sunlight will pass through the slit in the center of the paper. Hold a prism in the beam of sunlight coming through the paper. Your laboratory partner will hold a sheet of paper in the beam of light coming from the prism. Move the prism and paper until you can rest the paper on a table and the spectrum falls on the paper.
4. Keep the blackened thermometer bulb in the violet color of the spectrum for several minutes. Observe the rise of the mercury in the thermometer. When the temperature will go no higher, record the temperature in the data table.
5. Hold the blackened thermometer bulb in the blue color of the spectrum for several minutes. Observe the rise of the mercury in the thermometer. When the temperature will go no higher, record the temperature in the data table.
6. Repeat the above procedure, holding the blackened thermometer bulb in the green, then the yellow, orange, and the red color bands. Record the highest temperature of each color in the data table.
7. Hold the blackened thermometer bulb just beyond the end of the red color band for several minutes. Observe the rise of the mercury of the thermometer. When the temperature will go no higher, record the temperature in the data table.
8. Repeat the procedure, but hold the blackened thermometer bulb just beyond the end of the violet color band for several minutes. Record your data.
9. Repeat the entire procedure three times, allowing sufficient time for the thermometer to record the temperature at each color.
10. Using the data from your data table, construct a bar graph representing the determined temperature value for each color and beyond the visible color spectrum. Determine what temperature range you will use on your graph. Discuss your graph in your laboratory report, drawing interpretations where possible. How do you know that the electromagnetic spectrum extends beyond the visible color spectrum?

Data

TEMPERATURE OF SPECTRUM COLORS

	Trial 1	Trial 2	Trial 3	Average
Beyond Red	______ °C	______ °C	______ °C	______ °C
Red	______ °C	______ °C	______ °C	______ °C
Orange	______ °C	______ °C	______ °C	______ °C
Yellow	______ °C	______ °C	______ °C	______ °C
Green	______ °C	______ °C	______ °C	______ °C
Blue	______ °C	______ °C	______ °C	______ °C
Violet	______ °C	______ °C	______ °C	______ °C
Beyond Violet	______ °C	______ °C	______ °C	______ °C

Bar Graph

AVERAGE TEMPERATURE OF SPECTRUM COLORS	
Example	
Beyond Red	
Red	
Orange	
Yellow	
Green	
Blue	
Violet	
Beyond Violet	
Temperature	

DEGREES—°C

LABORATORY 24
MIRROR IMAGE

Introduction

Sound waves reflect from a cliff to produce an echo. Similar to sounds, light may be reflected. Light may also be absorbed or transmitted. Glass in a window, for example, reflects some of the light that falls on it, absorbs some of the light, and transmits most of the light to the inside of the classroom. Can you predict reflection, absorption, or transmission? What types of materials reflect light? What types absorb light? What materials transmit light?

One of the two theories discussed in the introduction to this unit considers light as being composed of particles. Thinking of a particle of light as a rubber ball, can you predict accurately the path of the ball if you were to throw it against a smooth surface? How will the angle at which you throw the ball compare with the angle at which it reflects (bounces)? Why is the corpuscular theory "better" than the wave-motion theory for describing light as the light falls on matter?

Problem:

How does a plane mirror form an image?

Materials:

Equipment
Mirror, plane
Straight pins
Metric rule
Protractor

Expendables
Paper, notebook
Cardboard, corrugated:
23.0 centimeters by 29.5 centimeters

Procedure:

1. Draw a straight line across the width of a sheet of notebook paper. Set a small mirror vertically on the line. Use a book to rest the mirror against so it will remain vertical. Be sure the edge of the mirror with the reflecting surface is the one placed on the line. The reflecting surface is usually the back surface of the mirror.
2. Set a pin upright in the paper about 5 centimeters in front of the mirror. A piece of corrugated cardboard placed under the paper will give a base into which the pin can be pushed. Can you see an image of the pin in the mirror? Where is it? Can you describe exactly where it is? How could you prove where it is?
3. Place your eye level with the paper and sight along the edge of a ruler toward the image of the pin. When it is lined up exactly, draw a pencil line along the edge of the ruler. Do the same procedure a second time using a different location for sighting the image.
4. Remove the mirror and extend the sight lines along the paper until they intersect. What does this intersection represent? Measure the distance of the intersection from the mirror line and compare with the distance from the pin to the mirror line.
5. How did the light rays travel in producing the image of the pin? Draw arrows on your paper showing how the light traveled. Label the angles of incidence (angle between the incoming light and a perpendicular line to the mirror) and angles of reflection. Draw the normal (perpendicular) to the mirror at the point where the light ray reflected. Using a protractor, measure the angles of incidence and reflection. How do they compare?
6. Carefully replace the mirror on the mirror line and repeat the procedure for two more positions of the pin. Label the pin positions A, B, and C. Connect these points with straight lines forming a triangle. After locating the image positions, label them A′, B′, and C′ respectively. Connect these points with straight dashed lines.
7. How does the image triangle compare with the object triangle (formed by the pins)? How do their sizes compare? How do their orientations compare with respect to the mirror line? How do their distances in front of and behind the mirror compare? Make a statement summarizing all the important conclusions concerning the formation of an image by a plane mirror.

LABORATORY 25
OPPORTUNITY FOR INQUIRY: HOW DO I START?

Elementary children in many school systems wish to enter science fairs. This is usually true of children who have been highly motivated by their teacher. After making the decision to enter the fair, their first step is usually to ask their teacher, "What can I do for a science fair project?" What will be your answer to this question?

Below are three short stories. The first describes how Isaac Newton discovered that white light is a mixture of colors (Laboratory 22). The second story describes the chromatic spectrum,

and the third describes how William Herschel discovered infrared radiation (Laboratory 23). These stories are typical of the kind of material available to upper grade elementary children. Following each story are two suggestions for inquiries. How many more suggestions can you think of for each story? Are these "good" suggestions for science fair projects? Choose one of the four and criticize it. Do the project, or collect eight or ten other similar science stories and write two inquiry ideas for each story. Consider each in terms of the grade you plan to teach.

A BEAM OF SUNLIGHT

Isaac Newton analyzed color by placing a prism in a beam of sunlight. The light was refracted (bent) into a color spectrum. Newton performed more experiments with the beam of colored light. He placed a second prism in the path of the beam of red light from the first prism and in the path of the beams of other colors of the spectrum. The results showed Newton that the colors are the fundamental colors of the spectrum, since they could not be broken into other colors. Newton's idea, then, was that white light is a mixture of the colors of the spectrum.

Research:

1. Would all white light from a bulb give the same result as sunlight when analyzed with a prism? Compare the spectrum of a white light from a filament light bulb, fluorescent light, and sunlight. Explain your results. Why does a photographer use blue flashbulbs when taking pictures indoors with outdoor color film?
2. Why do clothing stores use fluorescent lamps instead of filament lamps? Examine a colored object under a fluorescent lamp, under a filament lamp, and in sunlight. Does the object appear to be different colors under different light sources? Why?

WAVE LENGTHS OF LIGHT

You have seen a prism break up sunlight into a spectrum of colors. No matter what produces the chromatic spectrum, the colors are always in the order: red, orange, yellow, green, blue, and violet. Scientists have found that the different colors are due to different wave lengths of light. A wave length of red light is 1/30,000 of an inch long and a wave length of violet light is 1/65,000 of an inch long. When an electromagnetic wave, 1/65,000 of an inch long, strikes your eye, you see the color violet.

Other electromagnetic waves, longer than 1/30,000 of an inch long or shorter than 1/65,000 of an inch, are invisible.

Research:

1. Traffic signals have a red light for a stop signal and a green light for a go signal. Is there any reason for using red for stop and green for go? Could other colors be used instead of red and green? Devise an experiment to find why red and green are used in traffic signals.
2. Color or light is not a wave length; color and light are the sensations that are produced when certain electromagnetic waves excite the retina of your eye. Investigate the detection of other waves in the total electromagnetic energy spectrum.

INVISIBLE RADIATION

William Herschel was experimenting

with light in 1800. He wanted to find out if the different colors of light produced different amounts of heat. By placing a sensitive thermometer in the different colors of a spectrum, he found that the red color produced the most heat. When he moved the thermometer just outside of the red color, he could see no light, but the thermometer showed that heat was definitely present. From his observations, Herschel concluded that invisible radiation must be present. This particular invisible radiation causes the sensation of warmth when sunlight reaches your flesh. The invisible wave length is called infrared radiation.

Research:

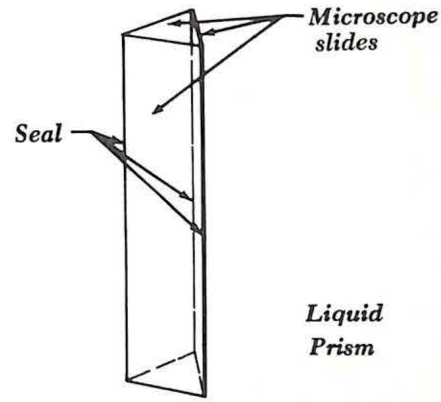
1. Find out what the infrared "snooperscope" is and how it was used in World War II. How does the "snooperscope" work?
2. Investigate infrared films. Take pictures in complete darkness with infrared film. How do pictures made in the daylight with infrared film differ from pictures made with ordinary film?

QUESTIONS

1. How would you define science? Has the definition of science changed over the past few years? Why?
2. What is the purpose of science? Why should science be taught in the elementary school?
3. Pasteur said that "chance favors (only) the prepared mind." What did he mean by a prepared mind? What implication does this have for science education?
4. How is a concept different from a fact? Is it important to draw a distinction between the two in your teaching? Why or why not?
5. Why is it possible to have two completely different theories of light? What does this show about the nature of science?
6. What is a spectrum? How is it formed?
7. What is meant by light reflection? Refraction? Give examples of reflection and refraction of light.
8. What color clothing should be worn in winter? In summer? Give evidence to support your answer.
9. You see lightning and then hear thunder. Does your eye or ear give you the most reliable information about where the lightning occurred? Why?
10. Draw a diagram to illustrate how a mirror forms an image. If an object is 2 meters in front of a mirror, how far in back of the mirror will the image appear to be?
11. How does the "fable of the lost child" in the introduction describe the process of science?

Further Investigation

1. Science equipment is not always available to the elementary teacher. Some teachers solve this problem by borrowing the equipment from local high schools, but others innovate. If you had no prisms, what would you do? A prism can be constructed from three microscope slides by fastening the slides together to form a triangular prism, then filled with water or some other liquid, as shown on the right. Make a prism from three microscope slides. The slides can be sealed together with transparent cellophane adhesive tape and one end can be sealed with the tape. Another method is to place the three slides in a wax block to form a triangular prism, sealing the edges with glue. Which method makes a better prism? Is water the best liquid to use in the prism?



Liquid Prism

2. The following demonstration may be useful in helping your pupils understand the nature of radiation: Freeze water in the shape of a lens. Use the ice lens to ignite paper by focusing the sun's rays. Ask why the paper burns when the ice does not melt.
3. Investigate the relationship between light intensity and distance from a light source. Place an overhead projector one meter from a wall. Measure the area of light focused on the wall. Measure the light intensity on the wall with a light meter. Move the projector 2, 3, and 4 meters from the wall and repeat the measurements. Graph your data. What relationship exists between light intensity and distance from the light source?

8

How are Electricity and Magnetism Related?

In the preceding unit, a fable was provided to illustrate how a theory may be formed. The boy in the fable formed a theory analogous in many respects to the way in which scientific theories are formed; the boy successfully formed a generalization that made successful predictions from observations in his environment. The boys' formation of a theory of burning objects represents the kinds of theories elementary teachers are asked to handle daily in the classroom. Some of these theories are so fundamental to the structure of science that many teachers are reluctant to modify or discard them. They tend to retain "cylindrical objects burn"-type theories as illustrated in the fable. Some of these theories become so thoroughly accepted that the average person actually "believes" them and does not even consider the possibility that they may be incorrect. On the other hand, elementary teachers should not overplay the uncertainties of science. Some pupils may become confused and disconcerted when presented with uncertainty, thus hindering their understanding of science. Understandings of science must come

first, then the limitations may be presented.

How were you taught science? What attitude did you develop if you were required to memorize long lists of scientific words, facts, or laws? Did this method communicate the tentativeness and uncertainties of scientific theories? It is not enough to just "learn" science words, facts, and theories. If scientific knowledge continues to double every decade, where will the learning of facts lead? The task for the teacher is one of communicating the nature and structure of science. Seven conceptual schemes, each representing a structure of concepts and facts, have been published in *Theories Into Action*[1], a document of the National Science Teachers Association. The document was published to furnish such a "structure of science" for curriculum development. This structure is being used in many of the newer elementary school science curriculums. It is hoped that the structure will enable the pupil to generalize from what he has learned so he can grasp general principles and apply his knowledge to other situations and to retain knowledge more effectively. The structure also should give the pupil a feeling of accomplishment for he can follow it logically as he communicates the intellectual achievements of science, as well as an understanding of how these achievements were obtained.

How were the intellectual achievements of science obtained in the topic of study in this unit, Electricity and Magnetism? In the "Fable of the Lost Child," the boy's theories were developed from what some call a "sudden insight" or a "flash of genius"—all of a sudden he formed a generalization that was successful in several predictions. This "flash of genius" is one way a new theory may be developed. The history of science will show many examples of how theories originate with such a sudden insight.

However, not *all* theories start with such a "flash of genius." Accidental observation, or chance observation, may also lead to a series of experiments which may, in turn, lead to a new theory. For example, Galvani made such a chance observation back in 1786. He noticed that when a frog's leg was touched with a metal scalpel, the leg twitched. He also noted that an electrostatic generator was in the room. This observation caused Galvani to plan many experiments in his search for an answer to the question of "why?" He even tried scalpels made of different metals and eventually discovered that two dissimilar metals in moist animal tissue created an electric current. His concluding theory was that the electricity came from the animal. Later, Galvani's records of his observations (laboratory reports) allowed Volta to invent the electric battery. Volta found that animal tissue was not necessary; two dissimilar metals and almost any moist material would produce the same results. This lead to a new satisfactory theory in which all of the observations concerning electric batteries fit.

Whether a theory starts with a "sudden insight" or "chance observation," you should not get the idea that this is all there is to science. No theory is formulated without many hours of investigations and previous work; the atomic theory was not established overnight, and men have been working on the atomic theory since the time of Democrates in about 300 B.C.

Regardless of how the theory was derived, science starts advancing with the

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[1]NSTA. *Theories Into Action* in Science Curriculum Development (471-14282), Washington, D. C., 1964.

testing of theories. Experimental science yields many new observations from experiments designed to test a theory. These observations become a chain of argument to support the theory. However, no number of observations will ever prove a theory; there is always some doubt—the theory is tentative. On the other hand, it takes only one observation to disprove a theory, as long as the observation is correct. Technical skill and precision are important in observations, not only for meaning, but for the interpretation of data. Related observations, concepts, theories, and experiments all are a means of exploring ideas. In the following laboratories, you will make observations and experiment. You will obtain your theories and concepts from the introductions and other readings. Can you combine these theories, concepts, observations, and experiments to further your understanding of electricity and magnetism?

LABORATORY 26 INVESTIGATION OF ELECTRIC CURRENTS

Introduction

What is electricity? In previous laboratories you have studied molecules—the unit of matter that retains the identity of that matter. Molecules are composed of one atom or combinations of different kinds of atoms, which in turn, are composed of even smaller particles. These particles are found in the center of the atom, the nucleus, and move around the nucleus. The nucleus of an atom is mainly composed of one or more protons and neutrons with electrons moving around the nucleus. An electron is the basic negative electric charge of the atom, a proton is the basic positive charge of the atom, and neutrons have no electric charge. Balanced atoms have a neutral electric charge. Electrons usually stay in the shell of an atom. The electrons in the outer shell of some atoms, however, can be forced out. These electrons, not bound to the atom, are free to form an electric current. An electric current is produced when something causes these electrons to move. The flow of electrons is called an electric current, or electricity. As you start the investigations of electric currents in this laboratory, remember that electrons have negative charges and move from negative to positive. Each laboratory will provide you with progressive learning toward the answer to the question, "What is electricity and how is it produced?"

Part A

Problem:

What is an electric circuit?

Materials:

Equipment:
Dry cells, 1½ volt, with binding posts
Insulated wire, 20 gauge
Flashlight bulb, 1½ volt

Expendables
Wood block, small
Thumb tacks, 2
Nail, 1 small
Clothes pin, wooden, with spring

Procedure:

1. Construct a flashlight bulb holder. Nail a clothespin to a wooden block, placing the nail through the center of the spring. The clothes pin does not have to be tightly secured to the block.
2. Remove about 5 centimeters of insulation from one end of a length of wire and wrap the bared end tightly around the grooves in the base of a flashlight bulb. Place the bulb in the clamp end of the clothes pin. Obtain another length of insulated wire.
3. Remove the insulation from one end of the wire. Twist the bared end of the wire once around a thumb tack and stick the thumb tack into the block directly under the flashlight bulb. Rub the top of the tack with steel wool to insure a good contact with the bulb base.
4. Remove the insulation from the remaining end of the two wires. Attach one end of one of the wires to one binding post of a battery.
5. Touch the unconnected end of the remaining wire to the other battery post. Answer the following questions in your laboratory report:
   (a) Why must there be two wires?
   (b) How is touching the wire to the battery post similar to closing a switch on a wall?
   (c) Which way are the electrons flowing? How do you know?
   (d) What is a circuit?
   (e) If you were to take one piece of wire and connect the ends of the wire to the binding posts of a battery, would electricity flow? Is this a circuit? Test your hypothesis and include your procedure and results in your laboratory report. Save the apparatus for Part B.

Part B

Problem:

Do electrons move (from atom to atom) more easily in some materials than in other materials?

Materials:

Equipment	*Expendables*
Beaker	Sodium chloride
Variety of materials	Sugar
plastics	
metals (penny, nickel, dime, iron nail, lead, zinc)	
Battery, bulb, receptacle, and wire from Part A	

Procedure:

1. Obtain the flashlight bulb holder constructed in Part A. Connect the wires to the post of a battery. The bulb should light.

2. Cut one of the wires half way between the battery and bulb. Remove the insulation from the cut ends. Test the bulb and battery by touching the loose ends together.
3. Obtain a variety of materials, such as plastics, metals, woods, etc. Touch the loose ends of the wires to the object being tested. Make a list of the materials that permit the bulb to light and those that do not. Include the list in your laboratory report with your answers to the following questions:
   (a) What is a conductor?
   (b) What is an insulator?
   (c) Why are some materials conductors and others insulators?
   (d) What categories of materials would be listed under insulator or conductors?
   (e) Are some materials better conductors than others? Are some better insulators? Are any part way between a conductor and insulator?
4. Fill a beaker half full with water. Place the wires under the water in the beaker, being sure the wires do not touch each other. Record your observations as you slowly add salt to the water.
5. Pour the salt water out of the beaker and wash the beaker and wires.
6. Fill the beaker half full with water. Place the wires under the water, being sure the wires do not touch each other. Record your observations as you slowly add sugar to the water. Answer the following questions in your laboratory report:
   (a) Is water an insulator or conductor? Salt solution? Sugar solution?
   (b) Why is it that both salt and sugar solutions are not conductors? State the source of your information with your answer.

Part C

Problem:

What is electrical resistance?

Materials:

Equipment
Insulated wire, 20 gauge
Dry cell, 1½ volt, with posts
Flashlight bulb, 1½ volt

Expendables
Pencil, lead
Masking tape

Procedure:

1. Obtain a long piece of thick pencil lead. Tape the lead, about 3 centimeters from both ends, to any flat insulator (see Part B for list of insulators).
2. Obtain two lengths of wire with the insulation removed from the ends. Connect one wire to one end of the pencil lead. Connect the other end of the wire to one post of a dry cell.
3. Wrap one end of the other wire around the threads of a flashlight bulb. Use a piece of tape to secure the wire. Connect the other end of the wire to the other post on the dry cell.

4. Place the base of the bulb to different parts of the pencil lead. Slide the bulb back and forth slowly on the lead. Include your observations with your answers to the following questions in your report:
   (a) Is the pencil lead a conductor? An insulator?
   (b) What effect does the pencil lead have on a flow of electrons? What does more lead do to the flow of electrons?
   (c) What is electrical resistance?
   (d) Do other materials have electrical resistance? Try a thick iron wire, a thin iron wire, a thick copper wire, a thin copper wire, and any other material or sizes of materials you wish to use, perhaps a very long thin wire. Include your results with your laboratory report.

Part D

Problem:

What other properties do electric currents exhibit?

Materials:

Equipment	*Expendables*
Thin insulated wire, 2 meters	Masking tape
Insulated wire, 20 gauge	
Dry cell, 1½ volt, with posts	
Compass, small	
Nail, iron, very large	

Procedure:

1. Place a small compass on a table. Position two books or other non-metallic objects on each side of the compass, one on the north side and the other on the south side of the compass.
2. Lay a length of insulated wire across the books in a north-south direction and directly over the compass. Tape the wire to the books. Place a non-metallic object under the compass so it is just under the wire.
3. Connect one end of the wire to one post of the dry cell. Touch the loose end of the wire to the other battery post several times. Record your observations. What does a current in the wire produce?
4. Remove the wire from the books. Hold it in a pile of paper clips or pins. Record your observations.
5. Obtain 2 meters of thin insulated wire. Obtain a large iron nail, a screw driver, or some similar iron cylinder. Wrap about 10 parallel turns of the wire around the iron cylinder. Stick the end of the nail into a pile of paper clips or pins. Connect the ends of the wire to a battery and again dip it into the paper clips or pins. Record your observations. How many pins or paper clips were picked up?
6. Wind 40 more turns of the wire around the cylinder. How many pins or paper clips will it pick up?

7. Wind a total of 100 turns of the wire around the cylinder. (It may be necessary to overlap some of the parallel turns.) How many pins or paper clips will it now pick up? Answer the following questions:
   (a) What is an electromagnet?
   (b) Where does an electromagnet obtain its magnetism?
   (c) What is one way to increase the strength of an electromagnet?
   (d) How else could the strength of an electromagnet be increased? Record your experiments and results on this question in your laboratory report.

LABORATORY 27
MAGNETS AND MAGNETISM

Introduction

The word "magnet" comes from the name "Magnesia," a city in ancient Asia. Magnetic rocks, called lodestones, were found near that ancient city. The earliest practical use of the naturally occurring magnets was as a compass to point out directions about 5000 years ago. The magnet has a number of properties that have an important bearing on your understanding of electricity.

Part A

Problem:

What is the nature of a magnet?

Materials:

Equipmnet
Bar magnets, 2
Iron filings
Variety of materials
plastics, metals (penny, nickel, dime, iron nail, lead, zinc, etc.)

Expendables
String

Procedure:

1. Obtain two bar magnets. Suspend one from a support with a piece of string. Bring the ends of the second magnet near the suspended one. Record your observations with your answers to the following questions:
   (a) How are the ends of a magnet different from the center of the magnet? Why?
   (b) What happens to a suspended magnet when another magnet is brought near it? Propose an explanation to this reaction.
2. Demonstrate the cause for magnetic activity. Place a sheet of notebook paper over a magnet on a table. Sprinkle iron filings on the paper. Make a sketch of what happens.
3. Repeat the above procedure to demonstrate the magnetic field with two magnets, when like poles repel and when unlike poles attract one another. The magnets should not touch. Make a sketch of both magnetic fields.
4. Repeat the above procedure, this time with one magnet and a piece of iron.

What do you observe?

(a) What is the nature of a magnet?

(b) What is a magnetic field?

5. Obtain materials tested in Part B of Laboratory 26. Test these materials with a magnet. What is your conclusion?

Part B

Problem:

How can you measure an electric current?

Materials:

Equipment	*Expendables*
Dry cell, 1½ volt, with posts	None
Compass	
Insulated wire, 20 gauge	

Procedure:

In Part D of Laboratory 26, you made an electromagnet. You may have found that as you increased the number of turns of wire or increased the current, the strength of the electromagnet increased. The strength of the magnetic field, therefore, indicates the strength of the current producing the magnetic field. How can this information be used to measure an electric current?

1. Obtain a compass and a length of insulated wire. Wrap the wire once around the compass. Connect the wire to a battery. Note how far the compass needle turns.
2. Disconnect the wire from the battery. Wrap several more turns of wire around the compass and complete the circuit. Measure the number of degrees the compass needle turns as you increase the wire turns on the compass. Construct a graph to show the relationship. The device you have made can be used as a current meter!
3. Keeping the number of turns of wire on the compass constant, connect a flashlight bulb between the battery and a compass. Compare the strength of the current with the strength of the current before the bulb was connected. Repeat the procedure, placing another bulb in a series (between the connected bulb and the battery). Measure the current. Place a third bulb in a series and measure the current. Remove the bulbs from the circuit and save your meter for the next laboratory.
   (a) What is your conclusion? How can a compass be used to measure an electric current?
4. Obtain a galvanometer. If possible, remove the cover of the meter. How is a galvanometer similar to your compass-meter?

LABORATORY 28
PRODUCING ELECTRIC CURRENT

Introduction

In 1820, Hans Oersted, a Danish physicist, published a paper in which he stated that electricity and magnetism are intimately related. Perhaps you discovered the same relationship in Part D of Laboratory 26, or Part B of the latest laboratory. Oersted discovered that a wire carrying electric current had a field of force around it similar to the field of force around a magnet. Oersted had obtained magnetism from electricity.

Eleven years later, Michael Faraday laid the foundation for our present methods of generating electricity. Faraday studied Oersted's discovery and wondered if the reverse were not true. Would it not be possible to produce electricity from magnetism? Faraday pondered over this question for years and performed many experiments before producing electricity from magnetism.

Part A

Problem:

How can electricity be created by a magnet?

Materials:

Equipment
Compass-meter from previous laboratory
Insulated wire, 6 meters, 20 gauge

Expendables
Masking tape
Paper cup

Procedure:

1. Obtain 6 meters of 20 gauge insulated wire. Wrap the wire around a paper cup, leaving the ends free. Remove the paper cup from the wire and hold the coil together with several pieces of masking tape.
2. Connect the wire coil to your compass-meter.
3. Hold the wire coil in one hand and a bar magnet in the other hand. Pass the magnet back and forth through the coil. Record your results.
4. Pass the coil back and forth over the magnet. Does it make any difference if the magnet or the coil is moved?
5. Obtain a crank-type generator. Locate the coil and the magnet(s).
   (a) Refer to Part A, procedure 4, question 2 of this laboratory. How does a generator produce an electric current?

Part B

Problem:

How can electricity be created by chemical action?

Materials:

Equipment	*Expendables*
Dime (silver)	Lemon
Penny (copper)	Masking tape
Compass-meter	
Insulated wire, 20 gauge	

Procedure:

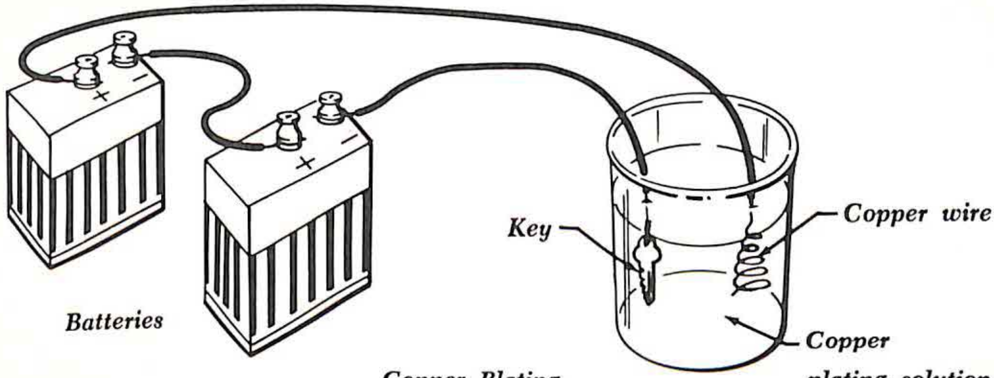
1. Clean a copper penny and a silver dime with steel wool.
2. Insert a copper penny half way into a lemon. Insert a silver dime into the lemon, about 3 centimeters from the penny. Be sure the coins do not touch.
3. Tape a wire from a compass-meter to the penny. Tape the other wire from the compass-meter to the dime. What do you observe as the circuit is completed each time?
   (a) How is the lemon like an electric battery?
   (b) The citric acid in the lemon reacts with the metals to produce electricity. Experiment with different metals in weak acid solutions (as vinegar). Determine what combinations of metals produce the largest current.

QUESTIONS

1. Discuss several ways scientific theories are formed.
2. How does the formation of a scientific theory advance science?
3. Compare the creative aspects of science with the creative aspects of art, history, and other areas of study.
4. Compare the tentativeness of science with the tentativeness of art, history, and other areas of study.
5. How is the study of science different from the study of technology?
6. What is electricity? Describe an electric current moving through a wire.
7. Describe several different ways electrons can be caused to move through a conductor.
8. Electricity and magnetism have been described as "first cousins." What does this mean?

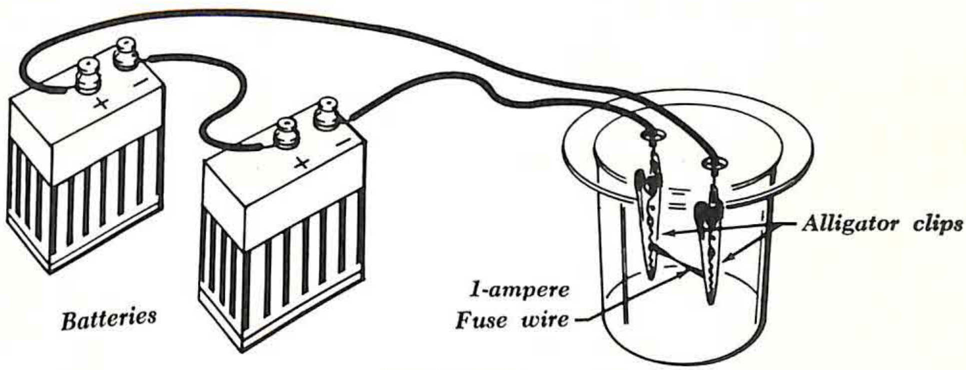
Further Investigation

1. Copper plate an iron object. Clean the object (iron of stainless steel) with steel wool. Dissolve blue vitriol in a beaker of hot water until no more will dissolve. Obtain two double post dry cells. Connect the negative (−) post of one cell to the positive (+) post of the other cell. Connect the object to be plated to the remaining positive post. Place the object to be plated in the blue vitriol solution, as well as the heavy copper wire. They should not touch. The copper plating can be removed by reversing the current.



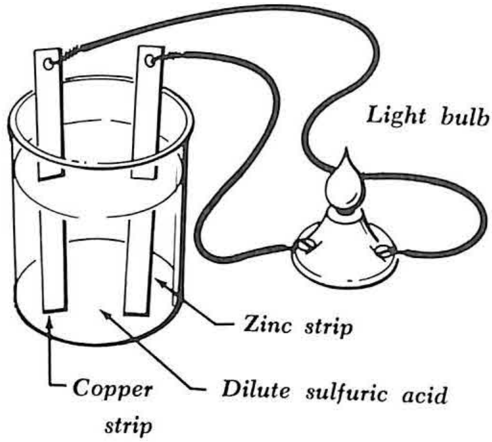
Copper Plating

2. Demonstrate how a fuse works. Obtain a large glass bottle and two very large iron nails. Cut a circle of cardboard to cover the top of the bottle. The nails should be about 5 centimeters apart. For the "fuse," connect a length of single strand picture wire between the two nails inside the bottle. Connect several dry cells in series (wires connected positive to negative). Connect the wires from the dry cells to the top of the nails. What happens? Could this also be used to illustrate how an electric bulb works?



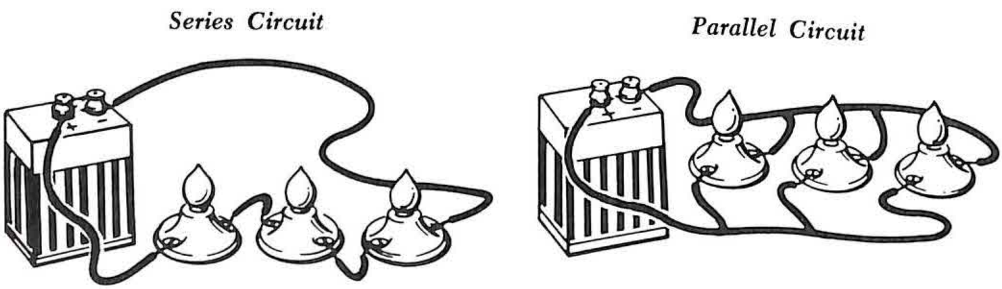
Simple fuse

3. Make a simple electric cell. Connect a strip of copper and a strip of zinc to a compass-galvanometer. Place the metal strips (they should not touch) into a solution of dilute sulfuric acid. Will your electric cell light a flashlight bulb?



Simple Electric Cell

4. Investigate the types of circuits. Obtain three flashlight bulbs and holders. Connect the bulbs as shown in the diagram. Unscrew one of the bulbs and then tighten it. Which circuit is similar to Christmas tree lights?



Types of Circuits

PART II

BIOLOGICAL SCIENCE

Introduction

The following section of the laboratory manual is devoted to activities in the biological sciences. The biological sciences are concerned with the study of living organisms, their growth and development, the changes of life forms, their structure and function, classification and all of the factors in the environment that influence their existence.

Biologists know life varies with the environment. The kinds of life in a desert often look considerably different from those in a coniferous forest. This difference presents an interesting question to the biological scientist. Why are there deserts and coniferous forests and why are they located where they are? After considerable study of this problem, scientists know certain factors within any environment limit the type of life living there. The deserts and coniferous forests are

mainly limited by the amount of rainfall they receive and their average annual temperature. The study of the interrelations of living things to each other and to their environment is a branch of biology called *ecology*. The lessons that follow are mainly designed to make you more aware of some of these interrelations and how they affect life. These lessons are designed to develop an understanding of ecological concepts and principles.

A concept is an abstraction that organizes objects and events into categories. Some examples of ecological concepts are desert, grassland, population, factors, communities, biome, and habitat. A scientific principle is a generalization about how nature operates. Examples of ecological principles are: "All living things have certain requirements that must be satisfied by the environment if life is to continue. Every environment has a potential capacity to produce or support a population of organisms. Plants must be adapted to the environment in which they live if they are to survive. For every species there is probably an average optimum temperature at which it grows most successfully, other factors being equal."

The principles of science are the fundamental generalizations about how phenomena operate in the world. If an individual knows these principles and knows how to apply them, he has fantastic intellectual power enabling him to function more effectively in his environment. It is for this reason that the learning of science principles is important. The responsibility for your teaching them in a comprehensive way on the children's grade level is paramount.

The following lessons generally give less guidance on how to do each activity than was given in the first section of the manual. This has been done because by now you should have gained enough confidence and awareness to know how to do an experiment and to give you opportunities to live for a time more like a scientist. When a scientist confronts a problem, he seldom has a set of steps and procedures outlined for him. He has to decide what direction to take. In fact, decision making is one of the most exciting aspects of operating as a scientist. From time to time, you may reach an impasse in doing some of the activities. If so, ask your laboratory instructor for help. He will ask you a few questions to help you gain insight to overcome your problems. Turn now to your next lesson and enjoy making discoveries as a scientist.

9

Preliminary Investigation—The Microscope

LABORATORY 29
HOW TO USE A MICROSCOPE

The microscopic community was opened as a frontier of science about 400 years ago when Conrad Gesner, a Swiss naturalist, used lenses to magnify the images of *Foraminifera* and protozoa in 1558. The history of the use of lenses, however, pre-dates the time of Christ, but the interest in them really did not blossom until the fifteen and sixteen hundreds when five men—Malpighi, Leeuwenhoek, Hooke, Swammerdam, and Grew—laid the foundation contributing to improving the scientific instrument. The improvement and perfection of the instrument has continued unceasingly, time allowing for more accurate and greater depth of vision into the world of the very small.

The microscope is a tool. Each science has its tools. The sciences that use microscopes extensively are: cytology—the study of the cell; histology—the study

of the tissue; and microbiology—the study of small organisms. The study of these sciences could hardly have advanced without the microscope. How could bacteria, for example, be studied without one being able to see them?

The history of the invention and development of the microscope indicates the importance of instruments to science. Often, in the history of science, there has existed a great "breakthrough" because of the perfection or invention of an instrument. This is also true today. Consider the computer and how its use will enhance knowledge. Instruments are extensions of man's senses; they help man see farther, hear better, record more quickly and more accurately, and think faster. Stop a minute and name an instrument that does each of these things for a scientist.

Microscopes are not generally inexpensive instruments. However, there are now available some microscopes serving the needs of elementary instruction costing not much more than $10.00. However, because many of these instruments are costly and sensitive, you should learn how to use them properly and with care.

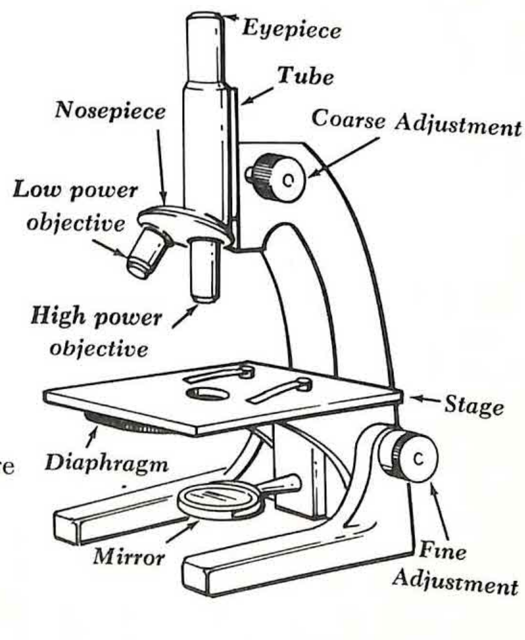
General Rules for Use of a Microscope:

1. When carrying a microscope, always carry it with two hands. This makes it unlikely for someone to brush against the carrier causing him to drop the instrument.
2. Never touch the lenses of the microscope with anything except lens cleaning tissue. The most expensive part of a microscope is its lenses, which will scratch easily.
3. When finished using the microscope, cover it with a plastic bag or some other suitable cover.

Parts of the Microscope:

Materials:

Microscope
Microscope slide
Tincture of Iodine
Elodea leaf
Spirogyra
Pleurococcus



1. Obtain a microscope and compare it with the diagram.

2. There are several types of microscopes, but they all function in about the same way. Learn the names of the parts of the microscope.
   Locate: (a) fine adjustment
   (b) coarse adjustment
   (c) eyepiece
   (d) nosepiece
   (e) objective
   (f) stage
   (g) diaphragm mirror or light source
3. Study the accompanying diagram. Explain in your own words how the lenses of the microscope magnify and make a large image.
4. If your microscope has a mirror, describe its purpose. Be accurate in describing what it does to the light.
5. When you move the coarse adjustment, what happens to the tube? Why is this important?

Part A

How to Prepare a Water Mount:

1. Obtain a leaf from the aquatic water plant *Elodea.* Place it on the middle of a microscope slide. Gently flatten the leaf out on the slide. Using a pipette (water dropper), place a drop of water on top of the leaf. Add to this one drop of tincture of iodine. Cover with a cover slip.
2. Place the microscope slide on the stage so that the *Elodea* section is directly over the aperture in the stage. Fasten the slide in place using the microscope clips.
3. Move the nosepiece so that the objective lens with the lowest magnification is directly over the slide. The magnification of an objective will be indicated on its side; for example, 10X means a magnification of ten times. Remember, however, there are lenses in the eyepiece. If they are also 10X, there will be 10X times 10X giving a total visual magnification of 100 times. Another way to tell the magnification difference is that in a group of objectives the shortest objective has the least magnification. *While watching from the side,* move the coarse adjustment so the tube is lowered as far as it will go. Do not touch the object with the objective lens.
4. Look into the eyepiece with one eye leaving the other eye open and gently move the coarse adjustment so the tube is moving toward the stage until the leaf comes into focus. In order to get a better adjustment, use the fine adjustment. This procedure should be followed whenever viewing anything under a microscope.
5. Sketch a diagram of what you see.
6. To change to higher magnification, first locate the object with the low magnification; then *look to one side* of the microscope as the nosepiece is carefully turned so the high-power objective is directly over the tissue. Use the fine adjustment to bring it into better focus. If this does not give a clear focus, change the objective to high power as before; at the same time, *watch from the side* and lower the tube so the objective is as low as it can go without

touching the slide. Look over the eyepiece and raise the tube slowly using first the coarse and then the fine adjustment.

CAUTION: With high power, the tube should never be adjusted downwards. This objective is much longer than the low-power objective and for that reason is more likely to hit the slide. It is very easy to crack a slide by turning the coarse adjustment downward too far. If the objective punctures a slide, it may not only damage the slide, but the lens as well.

7. If time allows, prepare other water mounts of *Spirogyra*, a filamentous algae that grows in streams, or *Pleurococcus*, a green powdery film found on the windward side of tree trunks. The *Pleurococcus* should be broken up with a needle and a very tiny amount placed on a slide. Look at some pond water to see if any organisms can be located. Draw what you see.

Part B
Study of Tissues

Preparing Semi-Permanent Slides:
Materials:

Razor blade, single-edged
Knife
Microscope slide
Cover slip
Glycerine
Piece of plant stem

1. Obtain a new stainless steel, single-edged razor blade, a knife, and a tender stem of plant. Cut across a stem with a knife. Place the flat surface of the remainder of the stem on a plate under water. While the tissue is under water, hold it gently with the fingers of one hand and with the other hand draw the razor across the surface making *very* thin sections.
2. After several pieces of the thin tissue have been cut, collect the thinnest on the razor blade. Slip them off onto the middle of a slide by pushing with a needle or a small paint brush. Add one drop of glycerine, which has been heated by standing a bottle of glycerine in hot water.
3. Cover with a cover slip by tilting the slip so that one side just touches the glycerine as the other side is slowly lowered over the whole section. A needle can be used to lower the cover slip more slowly. The lowering of the cover slip slowly is important because it allows the air to escape. If, however, air is still trapped under it, carefully tap the cover slip with a needle. The air will usually escape.
4. Make similar sections of root, leaf, and cork tissue. These slides may be kept for several weeks.

Robert Hooke (1635-1703) was the first to make accurate diagrams of how cork appears under the microscope. He called each of the pores he saw in the honey-comb-like structure a cell. Hooke, however, was actually looking at dead cells. You will see live cells in the root and leaf. Compare the characteristics of these cells with the dead cells of the cork.

5. Sketch a diagram of your observations of the stem, root, and leaf.
6. Do all the cells appear to look the same? How do they differ?
7. What is a tissue? Have you been looking at cells, tissues, or both? What is the difference?
8. Compare the outer cells of the stem with the inner cells. The structure of the outer cells differs. Biologists say structure and function are interrelated. Suggest how the structure of these cells enables them to perform a different function from the central cells.

QUESTIONS

1. Who invented the microscope? When?
2. On your microscope, what is the magnifying power of the ocular or eyepiece lens?
3. Using the above eyepiece, the magnification of an object on the stage as seen under *low* power is ____________.
4. Using a high, dry 43X objective lens, the magnifying power of the microscope is ____________.
5. Cedar oil has the same refractive index as glass and is, therefore, used with which objective lens? What is the magnifying power of a microscope using this objective lens?
6. The device just below the stage that serves to collect light falling directly on it or reflected on it by a mirror is a ____________.
7. If your microscope has several objective lenses, the structure holding them is called a ____________.
8. Upon what structure is the slide placed in viewing position?
9. Some microscopes can be tilted at an angle to the horizontal position. The structure that permits this bending is called ____________.
10. When should the above structure *not* be used?
11. What name is given to the specific kind of cells found in the inner cheek lining?
12. What name is given to the scientific "meat slicing" machine used to cut thin sections of tissue?
13. What physical method of fixing material to a slide is most often used?
14. In making permanent slides, what substance is generally used to fix the cover slip to the slide?
15. From your study of different kinds of cells, which kind always has a cell wall in addition to a plasma membrane?
16. What material should invariably be used to clean the ocular and objective lenses?
17. What *additional* substance is used to remove clean oil from the oil immersion objective lens?
18. What is the dark granular spot found in the cells of the onion root or leaf called?
19. What does N.A. on some microscope lenses mean?
20. List several types of microscopes used in biological investigations:

What are their special uses?

Reference:

Peter Abramoff and Robert G. Thompson, *The Microscope* No. 601 in Laboratory Outlines in Biology. (San Francisco: W. H. Freeman, & Co., 1963.)

10

Life Is Dependent upon Its Environment

LABORATORY 30

Problem:

What do seeds require in order to sprout?

Materials:

Paper towels
Plastic wrap
Seeds
Milk carton

Obtain several radish seeds, a large milk carton cut in half lengthwise, paper towels, some plastic wrap and other things required for seeds to sprout. The materials listed above are only suggestions for possible use. Design several experiments to determine what is needed for seeds to sprout. After you have made your preparations, it is suggested you take them home for observation. This

should indicate many elementary experiments can be done at home by the children you will teach. In this way you help to make science become more alive for children and they will realize that it is not just something a teacher does in the classroom.

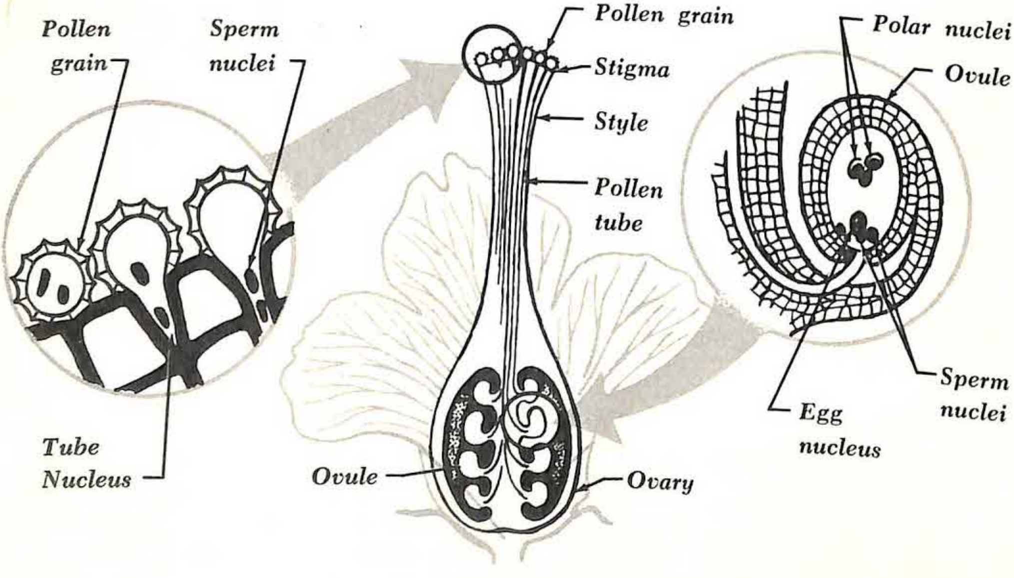
Observe your seeds for several days. Write a brief scientific report about your experiment. In doing the experiment you should get some ideas for further investigations. If so, describe additional experiments. Also, give a brief description on how you would improve your scientific accuracy if you were to replicate your experiment. Be prepared to discuss your results in class. How does this activity contribute to the understanding of the ecological principle: "Organisms are dependent upon and react to their environment"?

LABORATORY 31 WHAT IS POLLEN AND WHAT CAUSES IT TO DEVELOP?

The flower is the reproductive part of most seed plants. A typical flower usually has four distinct parts—the sepals, petals, stamens, and pistils.

Sepals are generally located at the base of the flower and protect it until it blooms. Petals are, in many flowers, brightly colored and serve to attract insects for pollination. The stamens and pistils contain the reproductive cells. Stamens produce pollen containing the male reproductive cells and pistils produce the female reproductive eggs.

Pollen may be carried by insects, wind, and birds to the pistil. When the pollen lands on the pistil, the flower is said to have been pollinated. The pollen then begins to germinate and will produce a pollen tube that grows down the pistil to its base where the egg cells are located. Once a pollen tube reaches the location of egg cells it enables male germ cells to join the egg cell and fertilize it.



Part A

Problem:

Where is pollen found and what does it look like?

Materials:

Microscope
Microscope slide
Flowers and flower parts

1. Obtain five different types of flowers, such as tulips, lilies, daffodils, narcissus, and geraniums.
2. Observe the flowers and locate the pollen bearing structures. Where is the pollen produced on the flower?
3. How are the pollen-bearing structures similar and dissimilar on the five flowers?
4. Place a small amount of pollen from each of the flowers on a slide and make a water mount. Look at the pollen under low power and draw what you see.
5. Repeat the above procedure for the other four flowers.
6. Make a water mount of some pollen from a conifer and sketch what you observe.
7. What conclusions can you make about the pollen?
8. What can you say about variations in nature from this investigation?

Part B

Problem:

How do pollen grains germinate?

Materials:

Microscope
Razor blade
Microscope slide
Plastic dish
Paper towels
Plastic wrap

1. Brush the top of a stamen against the top of the pistil. Separate the tip of the pistil from the flower by cutting it with a scalpel or a razor blade and place it in the center of a microscope slide. Place a few pieces of broken cover slip near the center of the slide where the pistil is located to support the cover slip. Crush the pistil in some water on the slide and cover with a cover slip.
2. Observe the pollen under the microscope.

3. Place the slides in a plastic dish on some folded soaking wet paper towel and cover the dish with a plastic top or protective covering.
4. Observe your pollen grains under the microscope for several days and record your observations.
5. Biologists know that various species of pollen sprout in different concentrations of sugar solution. Knowing this, how can you explain why the pollen germinated in the presence of the stigma? What would you do to prove your answer?
6. Outline an experiment to determine the concentration of sugar needed for a certain species of pollen to sprout.

Further Investigation

1. Determine the conditions at which one species of pollen will germinate the fastest.

11

How Are Organisms Influenced by Environmental Factors?

Life is influenced by several factors in the environment. These may include the quality and quantity of such things as light, heat, sound, water, humidity, food, the types of gases available, pressure, motion, acidity and alkalinity, and the numbers and kinds of organisms present.

The experiment you just performed on seeds presents many varied possibilities because you can devise experiments to test the influence on the sprouting of seeds of any of the factors in the above paragraph. For example, you might do experiments to determine if light is needed in order for seeds to sprout. Furthermore, you might do studies involving measurement of quantities, such as: If light is needed, how much? If water is needed, how much water? At what temperature will seeds begin to sprout? At what temperature do they sprout the best? Will

they sprout if put on a turning wheel? Does the speed of their movement have any affect? Look once again at the list of the factors given above and think of an experiment involving quantification for each of them. Be prepared to discuss your ideas in class.

Most elementary teachers realize the need for teaching science skills, but are often bewildered about how to approach such objectives. Usually several skills may be learned through investigation of subject matter areas. For example, the study of ecology lends itself well to the skill of quantifying data. This can be accomplished through an inquiry experiment. How can you teach such skills through an inquiry into ecology?

What factors may be involved in the life processes of any organism? This should suggest several possible problems for investigation. In the following activities, identify in your mind the most influential factors and then outline several problems. The process for doing this is simple. Take the list of factors about and ask: Does the presence of this factor have any effect? If so, how much effect? By following this procedure, you are learning to perform one of the most important acts in the scientific method—identifying problems. The list of factors given above is by no means complete. As you perform experiments look for other factors and suggestions for scientific problems that might arise from them. Keep a list of these to be handed in at the completion of the laboratory work. From time to time your instructor might encourage "brainstorming" sessions to elicit further ideas for investigation.

LABORATORY 32
FACTORS INFLUENCING THE GROWTH AND DEVELOPMENT OF PLANTS

Problem:

How fast do plants grow?

Materials:

Seeds
Milk cartons
Soil

Obtain several small milk cartons. Puncture the bottom of each carton for drainage. Fill the cartons with soil. Plant in the soil, one inch deep, three seeds in each carton as follows:

In two cartons plant beans,
In two cartons plant corn,
In two cartons plant radishes.

Water the soil in the cartons. Keep the soil moist, but not damp. Devise an experiment to test your seeds to determine if light or amount of water affects their growth. Remember to have a control for your test.

Make as accurate observations as possible. If more than one of the seeds sprouts in a carton, pinch the extra sprouts off at the ground, so that only one plant grows in each carton. One week after the seeds sprout, place a paper one centimeter wide next to the plant and cut it so that it is equal to the height of the plant. Do this for all your plants. Repeat this procedure each week for six weeks.

Keep a permanent record for each seedling by pasting the papers you cut measured to its height on one large piece of paper. You will have six measured cut papers pasted on each sheet and you will have six sheets when the experiment is completed.

QUESTIONS

1. What have you made from these cuttings of paper? What do these data show about seeds? Why is it a good technique for children to use in collecting data on growth?
2. What can you conclude about sprouting seeds and their growth from this activity?
3. Was this activity an investigation or an experiment? Why?
4. If you were going to repeat this activity, what would you do to be more certain of your results?
5. How would you use the activity to teach concepts of measurement?
6. Suggest other experiments similar to this activity. Is this an open-ended experiment? Why?

Reference:

The Elementary Science Study of Educational Services Incorporated, Watertown, Mass., has produced a unit "Growing Seeds" for children involving teaching graphing as illustrated above plus other science activities for children.

LABORATORY 33
FACTORS INFLUENCING THE GROWTH AND DEVELOPMENT OF ANIMALS

Problem:

What are some characteristics of animal growth?

All organisms grow and develop during their life. How they grow is to a large degree dependent upon their environment. Some species, for example, are dependent upon only certain types of food. The silkworm, for example, is mainly dependent upon mulberry leaves for its survival. Brine shrimp mainly eat nonfilamentous algae. The development of animals as they grow presents fascinating activities for children. They should have opportunities to observe several processes of growth and development in various forms of life. For this reason, several activities are suggested in this laboratory exercise.

Part A
The Growth and Development of the Frog

Materials:

Large jar
Tadpoles
Green aquatic plants

1. Obtain some frog eggs and pollywogs from a pond.
2. Place the eggs and tadpoles in a large jar or aquarium containing pond water from their environment with some green aquatic plants and algae. Lettuce may be substituted for this. Air should be pumped through the water. Why? Be careful that the jars are not in direct sunlight and remain at approximately room temperature.
3. Observe the development of the tadpoles over several weeks. Keep data sheets of your observations. Is this activity an experiment? From observing the tadpoles, what factors do you think are important for their development?

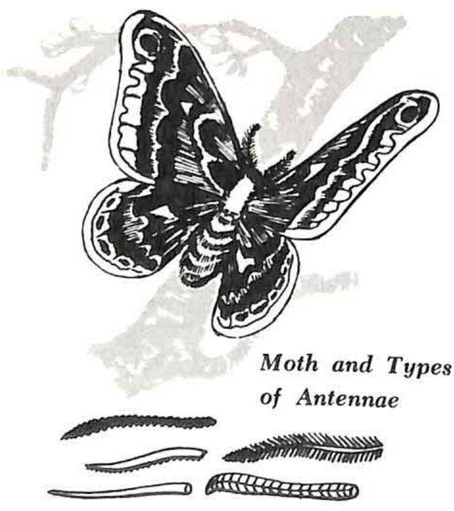
Part B
Metamorphosis of a Moth or Butterfly

(The following activity is preferably done in the Fall or Spring)

Materials:

Large jar
Cocoons

1. Obtain some larvae and cocoons or chrysali of *Cecropia, Polyphemus, Vanessa,* or *Promethea* or other *Lepidoptera* (butterflies and moths).



Moth and Types of Antennae

Butterfly and Types of Antennae

Place the larvae in a covered jar with some air holes in the lid and the types of leaves the larvae were feeding on. If you can find a female caterpillar or moth which you may recognize by comparison with a male—the female has a longer and thicker abdomen segment—place her in the jar as well. Place some twigs in the jar for the adults. From setting up and observing these organisms, what factors do you think are important in their environment for their development?

Part C
Development of Brine Shrimp

Materials:

Brine shrimp eggs
Small jars

1. Obtain some brine shrimp eggs and directions of how to raise them from the local pet shop. If you cannot obtain directions, consult *A Sourcebook for the Biological Sciences.* In raising brine shrimp prepare more than one culture to determine the effect of some factor in the environment on their growth. From observing brine shrimp development, list what factors you think important in their development.

Reference:

Brandwein, Morholt, *et al. A Sourcebook for the Biological Sciences.* (New York: Harcourt, Brace, & World, 1957.)

LABORATORY 34
OPPORTUNITY FOR INQUIRY
THE EFFECTS OF RADIATION ON CELLS

DIRECTION: This exercise is not a laboratory activity. It is, however, an invitation for you to inquire. Read the sections as directed and write the answers to the questions in the spaces provided. Keep in mind while doing the invitation how it could be adapted and used in the elementary school. Study the format of the invitation so if requested by your instructor, you could use it as a guide to write an invitation of your own on a different subject. In giving an invitation to a class, the written sections would be read aloud to the class and they would be asked to respond to the questions.

Teacher's Note: This lesson introduces the principle that radioactive radiation is harmful to cells. The lesson also shows a special research technique involving keeping cells alive outside an organism.

New cells are constantly being made in all living things. When you cut your skin, new skin is produced to repair it. Some animals are even capable of replacing whole organs. The starfish, for example, can replace one or more of its rays if they are cut off.

A scientist was interested in finding

out if cell division and the replacement of injured parts could be speeded up or slowed down. He thought radiation might have an effect on this process. He knew there were two types of radiation he could use to find an answer to this problem. At least one type of radiation is given off by radioactive chemicals, such as uranium or radium. The other type is produced by x-ray machines. He decided to use large doses of x-rays in his experiments.

1. If you were going to study the effects of x-rays on cells, what would you do?
2. What advantage would there be in using an x-ray machine over radioactive chemicals?

Scientists know today how to keep cells alive outside the body of a plant or animal. The process of keeping cells alive is called *tissue culturing.* Tissue culturing involves the taking of cells from a living organism and placing them in sterile dishes with a medium consisting of sterilized basic food substances and water. The liquids the cells give off in the tissue culture are frequently eliminated from the cells' environment. This is done so that the cells will not be poisoned by their own secretions. By using tissue culture procedures, cells have been kept alive for many years.

3. After reading about tissue culture, how could you use this technique to study the effects of radiation on cells?

The scientist decided to use two groups of cells in his studies. One group consisted of cells taken from the end of an onion root tip. The other cells were taken from the tail of a pollywog. The scientist x-rayed the pollywog's tail and the root tip cells and placed them in a tissue culture medium.

Two days later he checked his culture dishes. The cells from the onion root tip had divided many more times than those of the pollywog's tail.

4. What can be concluded from this information?
5. How could the scientist have improved his experimental procedure?
6. What should the scientist do next?

Teacher's Note: The scientist really should have used a control for the pollywog cells. He should have also varied a group of onion cells by x-raying them and keeping the other nonradiated cells for controls.

An invitation usually is not given in the form outlined above. It should be used in a discussion. Look back over the invitation. Without changing the invitation, what do you think would be the lowest grade level it could be used in? Explain your answer.

How many scientific concepts are there involved in the invitation?

How is the number of concepts included in a lesson related to children's ability to learn the material?

How would you build an understanding of the concepts used in this lesson?

What would you do to increase motivation in using the above invitation with children?

12

Changes in the Environment Can Cause Changes in the Behavior of Organisms

LABORATORY 35
BEHAVIOR OF MEALWORMS

Problem:

What can you learn about mealworms?

Materials:

Mealworms
Flat glass dishes

The science of the study of animal behavior involves the study of animals in an environment. The study may involve animals under conditions found in the normal habitat or they may be those established by an experimenter to determine the influence of some factor upon an organism and how it modifies the behavior of the organism. You may be only slightly aware of how changes in the environment affect your life. However, if you reflect on what you do during your leisure time in the winter compared to the summer you will begin to see how influential such changes can be.

Biologists are mainly interested in determining the normal behavior of animals in their habitat, while behavioral scientists, such as psychologists and anthropologists, are more likely to be interested in how behavior is modified and changed under environmental influences.

Obtain some mealworms. Observe them for several minutes and record what you think is their normal behavior. After you have done this, test them by varying as many factors as possible to see what stimulates or depresses their behavior. Record your findings and come to class prepared to discuss your results.

Further Investigation

Observe other animals similar to the one above such as: termites, snails, slugs, ants, or some other of your choosing. Determine their normal behavior, food habits, environmental preference and factors that may cause them to react differently. Write a paper as if you were going to present it to a scientific meeting indicating your results.

1. Refer to the *Sourcebook in the Biological Sciences* and *Sourcebook for Elementary Science* for helpful suggestions on how to raise and care for termites, ants, moths, butterflies, frogs, salamanders, fish, etc.
2. The Elementary Science Study of Educational Services Incorporated has produced a unit entitled "The Behavior of Mealworms" for grades 5-6. Read the unit. Prepare a critical evaluation of it and include how you think the unit might change the way children look at animals.
3. Suggest an experiment you might perform having to do with animal behavior.

LABORATORY 36
BEHAVIOR OF BRINE SHRIMP
(*Artemia*)

Problem:

How are brine shrimp affected by their environment?

Materials:

Hand lens or microscope
Brine shrimp

1. Obtain some adult brine shrimp in a small plastic bag or a glass container.
2. Observe them for several minutes and record what you think is their normal behavior. Look at them through either a hand lens or a microscope.
3. Note particularly the direction they are oriented when they move. What influences their movement?
4. Devise and perform an experiment to test the influence of some factor other than light on the brine shrimp. Write a report of your results.
5. Attempt to determine whether or not brine shrimp are phototropic. Tropism means "turning" and photo means "light," so phototropism means light-turning. If an organism tends to turn toward the light, it is said to show positive phototropism. If an organism turns away from the light it is said to show negative phototropism. Knowing this about a tropism, what do you think geotropism and hydrotropism means? Give several examples of organisms showing responses to these tropisms.
6. From your observations, give evidence why you think brine shrimp either are or are not phototropic. If you suspect they are phototropic, do you think they are phototropic to all wave lengths of light? For example, do you think they would be phototropic to red light? How would you go about trying to test your hypothesis?

LABORATORY 37
BEHAVIOR OF PLANTS—TROPISMS

Problem:

How do plants behave?

Materials:

Small potted plants, e.g. coleus, geranium or others
Aquarium
Bean seeds

Plants behave or respond to stimuli in many ways similar to those of animals. The following activity involves some of the ways they behave or react to stimuli.

1. In the previous exercise, you studied about phototropism, geotropism, and hydrotropism with respect to animals. The purpose of this exercise is to determine whether plants also respond to stimuli of light, gravity, and water.
2. Obtain two or three small geranium, coleus or other small potted plants. Devise and perform a test to determine whether they are phototropic or geotropic. Plants generally react to stimuli less noticeably than animals. For this reason the experiment you devise will probably take more than a week to perform. Make allowances for this when you set up your experiment.
3. Obtain several one-half pint milk cartons. Make two small punctures in the bottom for water drainage. Fill the cartons with soil and plant two or three bean seeds in each carton. Devise experiments to determine whether sprout-

ing bean plants are phototropic or geotropic. How would you proceed? Using colored cellophane attempt to determine whether sprouting bean plants are phototropic or geotropic. Using colored cellophane attempt to determine whether sprouting bean plants are phototropic to certain wavelengths of light. Your plants should be placed in an area where they will be undisturbed for two to three weeks.

4. *Group Activity*—One or more groups of students are to do the following activity to determine whether plants respond to or are stimulated by water. Obtain an aquarium or a large milk carton cut in half lengthwise. Fill the aquarium or carton half-full with sand. At one end of the aquarium or milk carton place a small porous flower pot in the soil. Stop the drainage hole of the pot with a cork. Plant bean seeds about every 5 centimeters apart and 5 centimeters deep in the sand. Place 10 cubic centimeters of water in the flower pot but do not water the soil. The water will pass through the pot to the seeds around it. Observe the sprouting and growth of the seeds for several days. After two weeks, pull up the plants and determine whether there was any indication that the plants were stimulated by water. Show your results to the class and ask them to make conclusions.

Do you think this was an experiment? Why?

If you were going to devise an experiment to test for hydrotropism what would you do?

What evidence might you gather from plumbers to determine the validity of an hypothesis about hydrotropism?

Thigmotropism means to react to touch. How would you show some plants react to being touched?

LABORATORY 38
BEHAVIOR OF PLANARIA—FEEDING AND REGENERATION

Have you ever seen planaria? What do they look like? Where could you find them? Find some now for experimentation. In the activities which follow, you will have an opportunity to discover more about the structure and function of these interesting members of the *Platyhelminthes* or flatworms.

Problem:

What changes in the environment influence the behavior of planaria?

Materials:

Dissecting microscope
Living planaria—Obtain from pond water by placing a piece of chicken liver in the pond for several hours. Planaria will collect on the liver.
Filtered pond water from place where planaria are found
Raw liver
Finger bowls
Desk lamp, gooseneck

Pans, rectangular, flat bottom dissecting or square aluminum cake pans
Pipette, medicine dropper
Needle, dissecting with dull point
Dilute solutions of salt, vinegar, or other substances
Ruler
Watch or clock with second hand
Razor blade, single-edge, new, sharp
Cellophane, different colored sheets

Procedure:

1. Place one or two living planaria with a small amount of pond water in a small bowl and examine them under a dissecting microscope. Describe their appearance and method of locomotion. Make a diagram of one of your planaria and label its parts. Find its pharynx. Describe the shape and location of the pharynx.
2. Fill a medicine dropper with pond water and slowly squirt water at a planarian. Repeat a few times. Describe what you observe. Suggest an explanation for this behavior.
3. Observe a planarian in normal or dim light and draw the path traveled by the animal during one minute. Now place a strong electric lamp 25 centimeters from the bowl and again draw the path of the animal during one minute. Compare your records under the two conditions of light. Describe any difference you notice. Explain.
4. Try poking an animal with a dull pointed dissecting needle or other probe. How does it react? Record your description. Explain.
5. How do planaria react to different chemical solutions? Try several. Record your observations. Explain.
6. Obtain three flat pans and number them 1, 2, and 3 with a marking pencil. Place about 2 centimeters of filtered pond water in each pan. Cut three pieces of raw liver about 2 to 3 centimeters square. Use a medicine dropper to obtain a flatworm. Place one living worm along the edge of pan number 1.
7. Place a piece of liver in the water at the end of the pan opposite the worm. Measure and record the distance between worm and liver. How long is it after you place the liver in the water before you detect any movement of the worm toward the liver? Record this reaction time in minutes and seconds on the graph following this laboratory exercise.
8. How long does it take the flatworm to reach the liver? Time the movements it makes toward the liver and record the number of inches traveled per minute on the graph.
9. Obtain a different flatworm and place it along the edge of pan number 2. Place a second piece of liver in the water at a third of the pan's length nearest the worm. Measure and record this distance. Again determine the reaction time (when you first detect any movement of the worm toward the liver) and record this on the graph. Time and record the number of inches traveled per minute by this flatworm in its path toward the liver.
10. Repeat the above procedure with a third worm in pan number 3, only this time place the liver at ⅔ the pan's length nearest the flatworm. Note and re-

cord the reaction time and number of inches per minute it takes the flatworm in traveling toward the liver.

11. What other kinds of food do you think planaria will eat? Change the water in all three pans and try some new flatworms with other kinds of food at the same or other distances of your choice. Note and record similar data for each different food on a new graph.

QUESTIONS

1. For each set of three pans with food at different distances, how many flatworms reacted to the food?
2. In which pan did the flatworm have the fastest reaction time to the food? The slowest?
3. Of the different foods you tried, which caused the flatworm to react the fastest? The slowest?
4. How do you explain the differences in reaction time of the three flatworms?
5. What did the flatworms do when they reached the food?
6. Why was a different flatworm used in each trial?
7. Do planaria react positively or negatively to light?
8. How do planaria usually orient themselves when in a stream of running water?
9. What is the characteristic reaction of planaria when poked with a dull probe?

Further Investigation

Planaria reproduce commonly either by transverse fission or by sexual fertilization. They also have highly developed powers of *regeneration*. This means they may be cut into different sections and the remaining pieces regenerate or develop the missing parts to form complete new animals. An interesting experiment may be done with a half dozen of your larger specimens.

1. Place specimens on a double layer of paper towel along with a few drops of pond water. Separate them into two groups of three each. Use a sharp new razor blade to cut the flatworms. One specimen in each group should be cut into thirds, and the remaining one may be cut in any manner you choose as long as you treat its counterpart from the other group in the same manner.
2. Place all the sections from one group in a small bowl labeled number 1 and the other group in another small bowl labeled number 2. Examine and study each group closely as to size and parts.
3. Record your observations by making scale drawings of each part to proper shape and size. Feed the sections in bowl number 1 with bits of liver, but do not feed those in bowl number 2. Put both bowls in a warm, dark place. Study the sections in both groups daily, noting all changes in shape and size by scale drawings. If, after the first few days, several of your planaria die, start over with some of the remaining animals.

QUESTIONS

1. What are your results? How do you interpret them? What conclusions can you draw from your data? What further experiments are suggested by your results?
2. Can you devise an experiment to test the reaction of planaria to different colors of light? How would you control the experiment?
3. What is the mechanism by which planaria detect food? What experiment would you do to test your hypothesis?
4. Can planaria learn? What experiment could you use to see if they do?
5. What processes of science have you used in these activities on planaria? What further investigations can you think of to help you discover more about flatworms?

Reference:

School Science Curriculum Project, University of Illinois. Unit on planaria. (805 West Pennsylvania Avenue, Urbana, Illinois 61801.)

ANIMALS REACTION TO FOOD

Flatworm Reaction Time

Use various colors or use various types of broken lines to record the movements of each flatworm on a graph similar to the one shown.

TIME (min.)

15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0

1 2 3 4 5 6 7 8 9 10 11 12

DISTANCE TRAVELED (in.)

Reaction times 1. ______ 2. ______ 3. ______

Average distance traveled per minute 1. ______ 2. ______ 3. ______

13

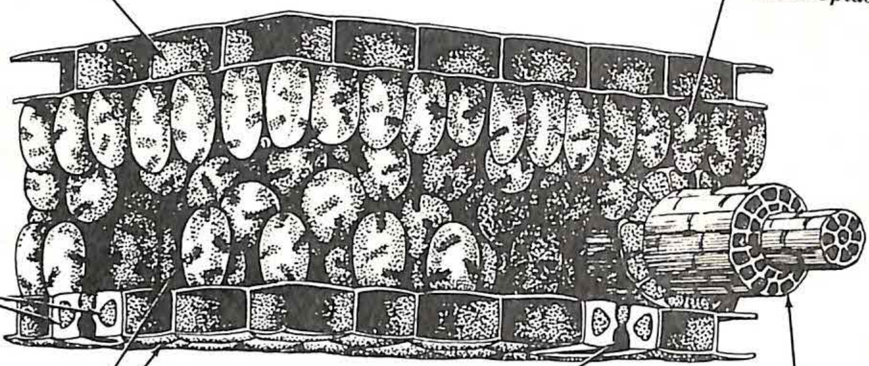
How is Man Dependent upon Green Plants?

LABORATORY 39
PLANTS MAKE FOOD BECAUSE OF CHLOROPHYLL—PAPER CHROMATOGRAPHY

Why is food-making in plants very important? What do you know about the different foods plants can make? Where are they made? What do plants use to make these foods?

One group of basic foods plants make is called carbohydrates. Carbohydrates are made of different amounts of carbon, hydrogen, and oxygen. These elements are combined by green plants in certain proportions to make sugar and these sugars can be converted by the plants into starch.

If you were to examine a cross section of a leaf from any green plant under the microscope, you would find it composed of several kinds of cells. The surfaces of a leaf are covered by a protective layer of cells coated with a waxy substance called *cutin*. Distributed over the leaf surfaces are small groups of cells having a



Cross Section of a Leaf

shape something like a mouth. Each group has a small opening in the center called a *stomate.* This pore is surrounded by two cells shaped something like lips known as *guard cells.* These guard cells respond to drying factors in the air. They open or close the pore depending on how much water the plant is losing. The loss of water by plant leaves is called *transpiration.* How could you demonstrate this loss of water by green plants?

Between the epidermal or surface layers are located the cells where photosynthesis or food-making takes place. These middle cells have chloroplasts containing chlorophyll, the pigment in leaves giving them their characteristic green color. It is known that each tiny chloroplast contains many stacks of discs called *grana* full of chlorophyll. In a way, this is only partly understood; these stacks absorb and store energy of sunlight in a form that can be used to combine water and carbon dioxide to produce sugar. Thus, the radiant energy of light is converted into chemical energy in food made by the plant.

Today most of the chemical changes that take place in photosynthesis are known. The process may be shown in the following overall equation:

$$6\,CO_2 + 12\,H_2O \longrightarrow C_6H_{12}O_6 + 6\,O_6 \uparrow + 6\,H_2O$$

This equation merely shows what substances go into and are produced by the process. It does not show the many complex intermediate chemical reactions that are known to occur.

In ordinary processes, matter may neither be created nor destroyed. Since plants use carbon dioxide every day, this means eventually they would use all the available carbon dioxide and there would be no more in the universe to use in photosynthesis. However, carbon dioxide and water vapor released as waste products in respiration by all living things serve to replenish the carbon needed by green plants in food making. Scientists as a result of more than a century of investigation know much about photosynthesis.

It is known that two reactions are involved in the process. When light en-

ergy strikes a leaf, some of the energy is absorbed by chlorophyll pigments. This increased absorbed energy by chlorophyll causes it to become activated, thus enabling it to split water into hydrogen and hydrogen-oxygen molecules. This first part of the process is called the *light-reaction*, because it only occurs in the light. The energy in activated chlorophyll is used to carry out the rest of the chemical reactions in photosynthesis not requiring light. For this reason, the second part of the process is called the *dark-reaction*, which involves a complex series of 20 or more steps using several enzymes, ending finally when carbon dioxide is fixed or combined to form glucose sugar. The generalized steps of photosynthesis are summarized below:

(1) Chlorophyll + light $\longrightarrow$ Activated chlorophyll

(2) Activated chlorophyll − HOH $\longrightarrow$ H + OH

Steps 1 & 2 are called the LIGHT-REACTION

(3) $H + CO_2$ through a series of chemical reactions and other compounds in the tissue $\longrightarrow C_6H_{12}O_6$

(4) OH through a series of chemical reactions and other compounds in the tissue $\longrightarrow 6\ H_2O - 6\ O_2$

Steps 3 & 4 are called the DARK-REACTION

Several pigments are found in the chloroplasts of green plant cells, including the familiar green chlorophyll *a*, which alone is able to split water and release its energy. Other pigments, such as chlorophyll *b*, xanthophyll and carotene, are also sensitive to light and transmit this excitation to chlorophyll *a*. These other pigments have the ability to absorb different wave lengths or colors of light and serve to collect additional radiant energy to carry on photosynthesis. What experiment could you perform to demonstrate that photosynthesis requires light in order to make food? Perform the experiment.

Most living things depend upon photosynthesis in order to survive. Living organisms either produce their food by this process or live off other organisms, which have obtained their food by this process. Some animals eat other animals. But the animals they eat, in turn, have eaten green plants for food. Because plants and animals are made of cells, they continuously use energy in the form of food. This food used in cells combines chemically with oxygen and gives off energy in the form of heat with released water vapor and carbon dioxide as by-products. This process of chemically releasing energy, water, and carbon dioxide is called *respiration*. How could you demonstrate that living things respire?

Problem:

How can paper chromatography be used to separate the several pigments found in the green coloring matter of plants?

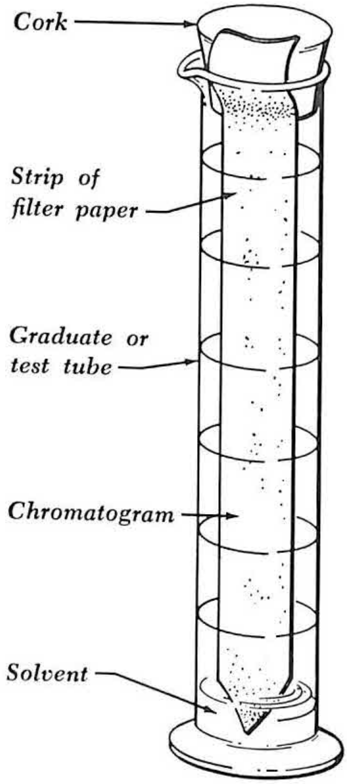
Materials:

1 test tube, 6″ × ⅝″

½″ strips of filter paper, lightly marked in pencil along one edge at ½ inch intervals of length

1 cork stopper to fit test tube
1 small paper clip
1 pipette or capillary tube
Acetone
Petroleum ether
Mortar and pestle
Various green leafy materials (spinach)

Procedure:



1. To prepare leafy solution, grind one medium to large size leaf with 10 milliliter of acetone in a mortar until pulpy. Filter the mixture and fill a pipette with this green liquid.
2. Place a drop of the mixture about ½″ up from the bottom of the filter paper strip. Make a small spot and allow to dry. Make this spot several layers thick by placing a drop onto the spot, let dry, and repeat several times.
3. Place about ½″ of a mixture of 8 per cent acetone and 92 per cent petroleum ether in the test tube.
4. Attach the filter paper strip to a paper clip imbedded in a cork.
5. Suspend the paper inside the test tube so that the spot is just above the surface of the solvent taking care to keep the tube in a vertical position.
6. Observe plant pigment separation until the solvent has almost reached the top of the paper strip.
7. Remove the strip and record observations of the separated color bands. Make a table or graph to show your results.
8. Prepare other chromatograms by using ivy or other green plants; try several kinds of plants, different parts of plants, plants grown in different environments of light and nutrition. Compare and explain any differences in your results.

QUESTIONS

1. What pigments were present in each leaf used?
2. What can be observed about the spaces between the color bands?

3. Did the pigments move equal distance? Which moved farthest? The least?
4. Which pigment is the most soluble? The least soluble?
5. What is the evidence that led you to these conclusions?
6. Why don't you see other colors of pigments in "green" leaves that you have separated out by this technique?
7. By comparing the results of several chromatograms, what can you say about variation in the kinds of amounts of pigments from plant to plant or in one kind of plant grown in different environments?
8. How would you use chromatographic methods to collect data on sea weeds or fungi?
9. Paper chromatographic methods have saved scientists innumerable hours in gathering data. Explain why the discovery of such a method may have helped accelerate scientific research.

Further Investigation

1. If you changed the proportions of acetone and petroleum ether used in the solvent mixture, what might happen? Try ½ acetone and ½ petroleum or ¾ acetone and ¼ petroleum ether.
2. What other experiments can you devise that will make use of this method of pigment separation? Try different colors of food dye or a mixture of two or three. Also, try different colored flowers.
3. What is the meaning of the word "chromatography?"
4. How does paper chromatography work?
5. To what other uses might this technique be applied? Try some that are suggested to you as a result of your previous investigations.
6. Could this technique be used to study pigments or other chemicals in animal tissues? If so, how?

References:

Johannes Van Overbeck, *The Lore of Living Plants*, Vistas of Science Book No. 8, NSTA, 1964.

AAAS, *Science, A Process Approach*, (Part 7 has a section on the extraction of chlorophyll, and its use in chromatography), New York, 1966.

LABORATORY 40
PLANT HORMONES

Problem:

How do hormones control plant growth?

Materials:

Coleus plants
Willow
Milk cartons
Gibberellic acid
Paper towels

1. Obtain several stems from *Coleus* plants and willow about 6 inches long. Wet the cut end of the stem in water and dip in the powder provided containing a hormone-like substance.* Plant the twigs two to each small milk carton containing sand and keep the sand moist. Design a procedure and determine *any* growth changes that take place over several weeks. Describe your observations.
2. As a group activity, obtain a pressurized sprayer can containing a solution made of gibberellic acid with 10 parts per million of the growth regulating substance.** Spray the solution on cuttings of geraniums and *Coleus*. Place your cuttings in milk cartons containing soil. Be sure to label your cartons with your name so as not to confuse them with other groups. Spray the cuttings every week. Note your observations and record.
3. Place some seed on a paper towel soaked with gibberellic acid solution. Use the same solution as used in the spray. Allow the seeds to remain over night. Plant the seeds the next day in small milk cartons containing soil and note any differences compared to a control. Describe your observations. What conclusions can you make about growth substances?

Further Investigation

1. Vary the concentration of spray used in spraying plants. Use 1 part per 1,000; 1 part per 10,000; and 1 part per 100,000. Note any differences in the growth of cuttings or leaves on a potted plant.
2. Obtain some 2,4-D from the local nursery or hardware store. Use various dilutions and spray it on different plants to determine its effect at different concentrations.
3. Read a botany book about plant and animal hormones and make a list of the commercial application of these substances.

*The commercial hormone is produced under such names as Auxilin, Hormodin, Quick-Root, Rootgro, and Rootone, plus others. These can be purchased from the local florist or ten-cent store.

**Gibberellic Acid Solution may be prepared by obtaining 450A590 Turtox Gibberellic Acid "10" Powder from the Turtox General Biological Supply House, 8200 South Hoyne Avenue, Chicago, Illinois 60620. Dissolve two and one-half grams of powder in a pint of water to make a solution containing 10 parts per million of active gibberellic acid.

14

How Are Communities of Organisms Interdependent?

LABORATORY 41
THE COMMUNITY OF THE POND (OR AQUARIUM)

Where have you taken a field trip in your science classes? How are field trips important as learning devices? Some elementary teachers take their classes on field trips to a local pond so their children can learn about the changing relationships and interdependencies among plants and animals and their environment. If there were no local pond in your vicinity, what would you do to substitute for this investigation? In this laboratory, you can discover how a classroom aquarium filled with pond water can substitute for a pond. The aquarium offers many chances to make careful observations and to record data by determining the changes taking place over a four to six week period of time.

Problem:

How can an aquarium substitute for a visit to a pond?

Materials:

Aquarium, 1 or more, preferably 15″ × 12″ × 12″ or larger (or wide-mouthed gallon glass jars)
Pails for transporting pond life to classroom aquaria
Bottles, sample, 125 mililiter gas collecting to determine water's oxygen content, etc.
Pipettes, 1 mililiter
Depression microscope slides and cover slips
Vaseline
Microscope
Medicine droppers, graduated
°Chemicals: manganese sulfate; potassium hydroxide; potassium iodide; sulfuric acid; sodium thiosulfate; sodium hydroxide; phenolphthalein.
pH paper

Procedure:

The materials needed to make a balanced aquarium include various amounts of pond or stream water with animals, vegetation, and bottom mud or sand. The live materials and water should be collected from a pond. All of these should be transported separately in conveniently sized containers for ease of handling. It is best to locate the aquaria or large glass jars in the classroom near a north wall out of direct sunlight and away from heat sources. Use care in filling the aquaria. Make sure they do not leak. If mud is used with sand for the bottom, cover the top of the sand with heavy wrapping paper and pour the pond water in slowly to avoid mixing the mud. Remove the paper when the tank is almost filled. Distribute the plants over the bottom and let the aquarium adjust or settle for a day or so before making and recording any observations. Collect water samples in glass bottles for tests on oxygen content, carbon dioxide content, and pH.

1. To test for oxygen content of actual pond water samples or aquarium water samples, add the following chemicals to the oxygen sample: 1 cc $MnSO_4$ and 1 cc KOH-KI. Replace the stopper and mix by inverting the bottle. Add 1 cc H_2SO_4 and remix. This is the *iodine point;* the sample can be carried to the lab for titration. After 10 minutes or in lab, titrate with $Na_2S_2O_3$ (sodium thiosulfate); use 1 ml starch to obtain a refined end point. (#cc $Na_2S_2O_3 \times 2 =$ ppm O_2)
2. To test for pH, decant 25 ml of the CO_2 sample into a white evaporating dish. Add pH paper with clean forceps and determine pH by color comparison with graded standards.
3. To test for CO_2, add the remaining 100 ml of the CO_2 sample; 10 drops phenol-

phthalein indicator. Titrate with N/44 NaOH until a permanent (+1 min) pink appears. (#cc NaOH $\times$ 10 = ppm CO_2)

4. To determine number of organisms, decant 100 ml of sample into a condensing net made of fine (#20) botting cloth which serves to concentrate the plankton (microscopic animals and plants). Preserve specimens with formalin (1 part of drugstore 40% formalin to 9 parts of sample). Using a simple formula, one may quantify the catch in organisms per liter thus:

$$\frac{\#/\text{ml concentrate} \times \text{ml of concentrate sample}}{\text{ml of pond or aquarium water sample}} = X$$

$$\frac{X}{1{,}000}$$

where X = # of organisms per liter of pond water

QUESTIONS

1. What changes do you expect will occur in the numbers and kinds of organisms present over the observation period? How will you take your samples? How often?
2. What changes do you expect will occur in the oxygen content, salt content, and pH of the water? How often should you test for these? When?
3. How will you determine the initial physical and chemical characteristics of the aquarium?
4. How can you estimate the relative numbers of different organisms present?

Behavioral Outcomes:

In this lesson you formulated hypotheses, made observations, recorded data, interpreted the data, and drew tentative conclusions. You also devised tests for the kinds and numbers of organisms present and became acquainted with problems of sampling and prediction in doing biological investigations. What other types of scientific processes were involved in this lesson?

Further Investigation

1. Compare the changes that occur in one or more natural pond or stream environments with the changes in the classroom aquarium and suggest what might be the cause(s) of the changes.
2. Place one aquarium on the north side and another on the south side of the classroom and compare any differences that occur over several weeks.
3. Obtain some mud and stagnant water or water escaping from a septic tank. Place it in a jar and seal the jar. Observe and describe any changes that occur over several weeks.
4. Consult a local pet shop and set up a salt water aquarium and observe it over several weeks. Record your observations and any problems that you encounter. What differences are there between fresh and salt water aquaria?
5. Obtain several local aquatic snails and some *Elodea* and several different

sized test tubes. Seal a snail with a given amount of *Elodea* in each tube and observe the effect of the tube size on the interrelationships of snail and *Elodea*.

Reference:

William B. Nutting, "Biology of a Pond," *American Biology Teacher* (May, 1966) pp. 351-360.

LABORATORY 42
THE COMMUNITY OF THE SOIL

Man has traveled world-wide in search of wild animals. However, beneath man's feet lie the wonders of another animal world—the world of small animals without backbones. These animals are known as invertebrates.

Problem:

What small animals live in different types of soil?

Materials:

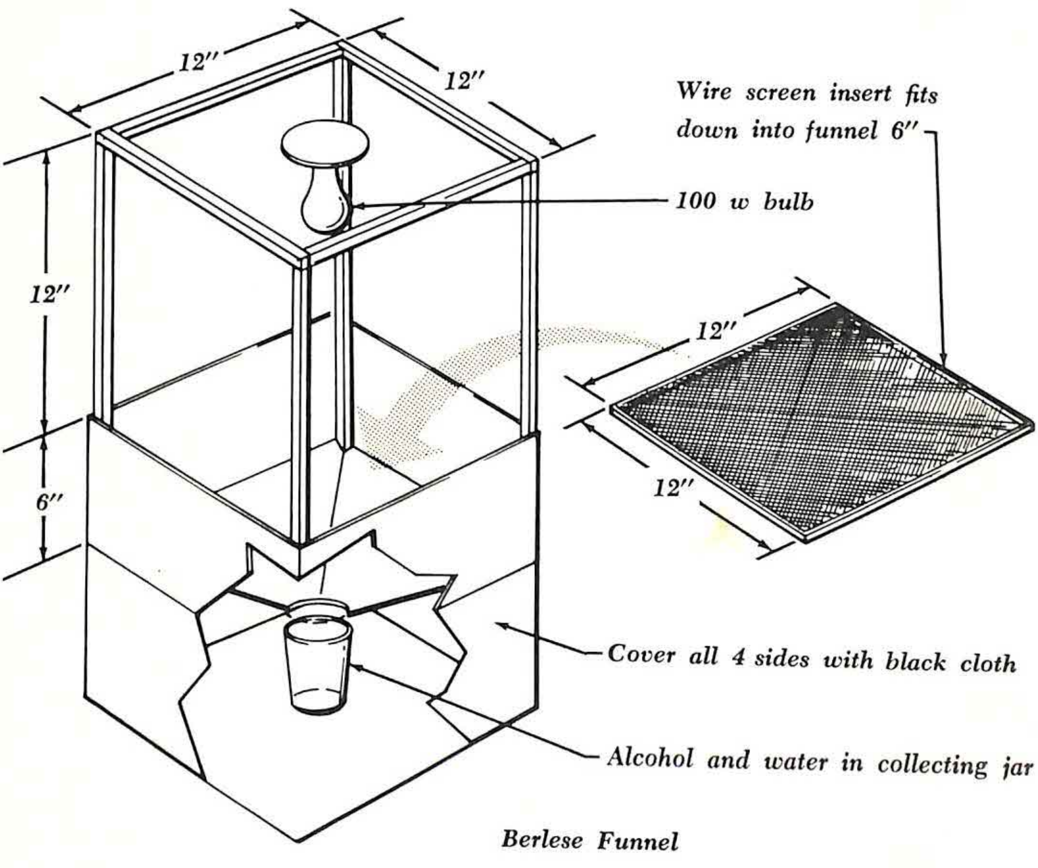
Funnel, 6 inch
Tube, rubber to fit above funnel
Clamp, rubber tube
Bottle, wide mouth, half pint
Stopper, rubber, one-holed, to fit above bottle and funnel
Alcohol, dilute
Berlese funnel (see diagram)
Screening, wire
Spade, preferably square-ended
Bags, polyethylene plastic, gallon size
Dissecting microscope or hand lens

Procedure:

1. Collect a variety of soil samples from different habitats, including a swamp, river bank, mountain slope, prairie, desert, forest, along a ditch bank, or a hard dry roadside. Soil samples should be about a gallon in size or about a half cubic foot and of uniform dimensions. The sample should be cut from the top foot of the selected habitat with a square-ended spade or shaped uniformly with a knife or other tool. Put the samples of soil in gallon plastic bags and label each with the date, location, and type of vegetation in the area.
2. Place a small animal trap in the hole from which the soil sample was taken. The trap can be made by fitting a 6 inch funnel into a one-hole rubber stopper that fits a wide-mouthed bottle. Place the trap in the ground so the top of the funnel is level with the ground. Cut a small hole in the center of a piece of wire screening 7 or 8 inches square and crimp it over the top edge of the funnel. Cut the top off a cardboard box and a part of the sides and place the

box over the hole to prevent rain or snow from getting into the bottle and drowning the animals. The animals trapped in this way may be examined, identified, and recorded daily; then set free so as to retain the balance of nature.

3. The half cubic foot soil sample is placed on the screening in a Berlese funnel and the electric bulb turned and left on at least over night or for a day or two. The Berlese funnel consists of a box-like support for the funnel with an electric light mounted under the top cover of the box and the part from the funnel downward covered with black cloth. The heat and light from the electric bulb causes the animals to come out of the soil into a small jar placed beneath the funnel. The jar should contain a little dilute alcohol to prevent the escape of the flying insects. Examine the small animals collected in this way.



Berlese Funnel

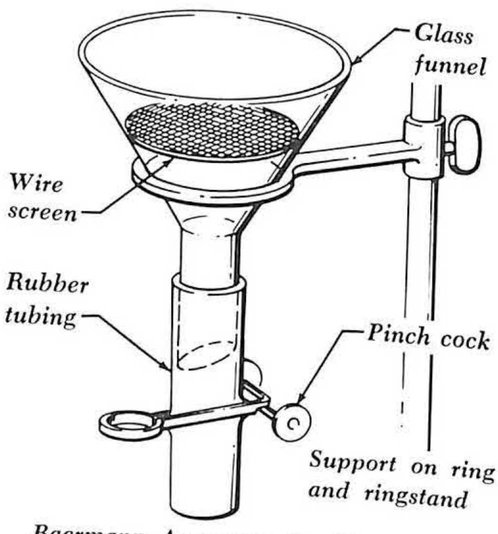
QUESTIONS

1. Examine the several types of animals you have collected. Write a brief description of each type you observe.
2. What are the relationships between the forms of animals discovered and the environmental conditions of the habitat in which they were found? What did you find out about amount of moisture? Temperature? Acidity? Amount of organic matter present? Type of soil?

3. How do your results compare with other class members who have soil samples from similar or different habitats?
4. Why are these animals found in the soil in a specific environment? Do you notice some soils will have only ants while others will have earthworms? What are the life cycles of some animal forms you have found?
5. What relationship, if any, exists between the size of the animals you have found and their relative abundance? Is this true in all soil samples?
6. Describe five conditions of the soil habitats that permit the animals to live in them.
7. How could this investigation be improved in order to secure more accurate information?

Further Investigation

1. A Baerman funnel (see diagram to the right) may be used to collect small roundworms, known as nematodes, from your soil samples. Such a funnel is simply constructed by attaching a short length of rubber hose to the funnel neck and attaching a hose clamp to the rubber tube. A circular piece of wire screen is cut to size so that it fits about a third of the way down the funnel. Place your sample of soil in a small piece of cheesecloth on the wire screen in the funnel, loosen the clamp and fill the funnel *from below* by lowering the funnel mounted on a ring and ringstand into a vessel of water until the water just touches the bottom of the sample and then clamp the rubber tube shut. The worms will become active in the water and swim out of the soil. After the apparatus has been standing overnight, the worms may be drawn off from the rubber tube. You can tell nematodes easily by their worm-like appearance, but identifying them is a difficult task.



Baermann Apparatus for Nematodes

2. Design an experiment to test the decomposition action of soil microbes on different organic materials or compare the rates of decomposition of different soils.

LABORATORY 43
THE FUNGI COMMUNITY

A student may bring you a "puff ball" and ask what it is. How can you develop a science lesson from this opportunity?

Fungi are plants which are unicellular, as in the case of yeast, or multicellular as in the case of molds, puff balls, mildews, rusts, and mushrooms. Molds are fungi commonly seen growing on cheese, oranges, bread, and other

decaying foods. Fungi are either parasitic, growing on a living organism, or saprophytic, growing on dead organisms. Fungi have to grow on organic material, because they lack chlorophyll and cannot produce their own food by photosynthesis. Fungi reproduce by small microscopic spores that easily float on air and are widely dispersed. Spores of some varieties of fungi have been collected by aircraft flying thousands of feet above the earth. If fungus spores fall on a suitable environment supplying necessary organic material and other conditions, they will sprout and produce fungus plants.

Problem:

How are fungi produced and studied?

Materials:

Plastic wrap
Bread
Orange peel
Moldy cheese
Unmoldy cheese
Hand lens

Procedure:

1. How can you set up some experiments for growing or increasing the growth of mold on different substances? Try to determine the conditions at which the mold will grow the fastest. You are encouraged to take some or all of these preparations home and observe them from day to day. However, bring your preparations back to the next laboratory session. Record your observations of the molds.
2. In the second laboratory session, observe your mold as closely and as accurately as possible and record the observations.
3. List any conclusions you can make about molds from having done this laboratory investigation.

Further Investigation

1. Determine by experimentation what factors inhibit the growth of fungi.

LABORATORY 44
THE BACTERIA COMMUNITY

Fungi may be organisms of only one cell. There are even smaller organisms—bacteria, for example. How can you study bacteria in the classroom? Bacteria surround us. They are found in all parts of the environment and are distributed from various places where they grow. Bacteria have been found in deep caverns, on the floor of the sea, in Antarctica, scattered over all the earth's surface, as well as high in the atmosphere.

Problem:

How are bacteria distributed in nature?

Materials:

Sterchlor solution for sterilizing work areas
Sterile petri dishes, glass, or disposable plastic culture plates (1 for each class member)
Sterile nutrient agar, 25 mililiters in screw cap bottle *or* plain gelatin and bullion cube
Sterile cotton swabs
Sterile water
Metal pot
Tripod, or ring stand and iron ring
Bunsen burner or other heat source
Hand lens or dissecting microscope
Cardboard colony count discs
Living cultures of: *Bacillus subtilis, Escherichia coli, Aerobacter aerogenes, Proteus vulgaris* (obtained from neighboring college bacteriology departments.)

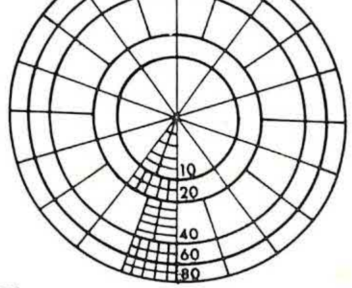
Procedure:

1. Work in teams or as directed by your instructor. First sterilize the table top or other working area by sponging the surface with Sterchlor solution. If you use nutrient agar, loosen the cap of the bottle of nutrient agar, but do not remove it. If plain gelatin or bullion is used, skip step 1 and go to step 2. Place the bottle in a pot and add water until the level is the same as the level of the agar in the bottle. Bottles from several teams may be placed in the same pot. Heat the pot until the water boils and continue heating until all the agar in the bottle is melted. Next add cold water to the pot and stir until the temperature of the water is about 45°F. At this temperature the bottle can be removed from the pot and handled without discomfort.
2. To prepare a culture medium of plain gelatin and bullion, add the contents of one envelope of gelatin to a cup of boiling water and dissolve one bullion cube in this mixture. Stir until the ingredients are dissolved and continue to stir as you add one-half cup of cold water.
3. Pour the nutrient agar or gelatin medium while still warm into the culture dishes, filling each dish to a depth of about 1 centimeter. Cover the dishes and set them aside to cool.
4. Where would you look for bacteria? Dip a sterile cotton swab in sterile water and swab some surface that you think has bacteria on it. One student might choose a corner of a blackboard or laboratory table, another the back of a chair, a third a pane of glass in the window, etc. Each team member should now carefully touch his dish by streaking the surface of the agar with the contaminated swab. All team members should immediately record the data in a

chart like that in columns 1 and 2 of the chart below. The number of the control dishes should be entered in the chart. No colonies should develop in the controls; hence, no data for these should be entered in column 3 of the chart. However, if colonies develop in the controls, they should be described. Why?

Culture Dish No.	Surface Tested	No., Type of colonies	Colony Cross section	Type of edge	Colony Texture

5. Each team should prepare a set of culture plates using a separate plate for each of the living cultures provided. Streak the surface of the medium with each type of organism. One or more teams may check the inhibitory effect of a heavy metal on bacterial growth. This is done by first cleaning pennies, one for each type of organism available, in a dilute solution of nitric acid and then thoroughly washing them with sterile water. Using sterile forceps, place a penny on the surface of the medium and then either streak the plate with the test organism or add a little of a suspension prepared from each type of culture to the medium surface. How do the cultures containing the pennies compare to those having the same type of organisms without a penny? Can you explain any differences you notice?
6. Examine a slide prepared from each of your cultures under a microscope. What is the shape of the individual bacterium? Do these shapes vary from organism to organism?
7. Inspect the dishes daily to observe any colonies which have developed. After several days, when no new colonies have appeared, use a cardboard disc plate counter marked into quadrants similar to the diagram on the right. Determine the total number of colonies of bacteria, fungi, and molds that have developed in your dish, as well as in the controls. Each colony most probably represents a group of organisms developed from a single organism. Some colonies may be mixed. Here two or more organisms located close together on the surface tested have given rise to a single colony. In some cases, some parts of such a colony will have a different appearance than others. Examination with a hand lens or dissecting microscope will usually



Glass Counting Plate, Stewart (or cardboard disc)

Ruled area 110 mm diameter divided by radii and concentric circles for counting numbers of bacterial colonies

enable you to distinguish between colonies of molds and bacteria. Look at the colonies from the side and describe the shape of the cross section of different colonies. Mold colonies will have delicate thread-like structures visible at their edges. These will be absent in bacterial colonies, which usually have smooth edges. Observe the surface of these colonies. Record and describe their textures in column 3-6 on the chart.

QUESTIONS

After studying the data obtained from all the members of your team, plus that from the controls, answer the following questions.

1. From which location was the greatest number of bacteria collected? The smallest number?
2. From which location was the greatest number of fungi collected? The smallest?
3. From which location was the greatest number of molds collected? The smallest?
4. On the basis of your results from these activities, can you detect any patterns in the distribution of microorganisms?
5. Were any colonies present in the controls? If so, how can you explain their presence?
6. Why would it be reasonable to believe that, in every case, more microorganisms were actually present on the surface investigated than were represented by colonies in the culture dishes?
7. How widely are microorganisms distributed in nature?

Further Investigation

1. A very interesting part of the history of science is centered around disproving the theory of spontaneous generation. Trace the development of these ideas from Aristotle to Pasteur by reading John Tyndall's account of this story in a two-part article on "Spontaneous Generation" published in 1881 (Vol. 12, pages 476-488 and 591-604) of *Popular Science Monthly*.
2. Use a Fisher or Durham fermentation tube for checking production of gas by the various cultures of organisms with which you have been working. Try a culture of yeast for its fermentation activity.
3. Try the effect of different common household disinfectants and antiseptics on bacterial growth of these same cultures.
4. Take a field trip to the local water purification plant, sewage disposal plant, and public health service to find out how these agencies help to prevent, control, and fight various diseases.
5. Write to the Communicable Disease Center at Atlanta, Georgia and ask for films and filmstrips available on different infectious diseases. Also, ask for their record of endemic and epidemic diseases in your local community or state.
6. The Elementary Science Study of Educational Services, Inc., 108 Water Street, Watertown, Mass., has produced a unit for sixth grade called *Microgardening*. Consult this unit and list some of the ways you could use it to teach science as a process. Are there any parts of the unit you think could be used or modified to give children opportunities to be creative?

7. Write to Chas. Pfizer & Company, Inc., 235 East 42nd Street, New York, New York 10017 and ask for reference materials on molds and other antibiotic producers.

Reference:

René Dubos, *Pasteur and Modern Science*, Science Study Series, paperback, No. 15. (Garden City, New York: Doubleday and Company, Inc., 1960.)

LABORATORY 45 INTERRELATIONS OF MICRO-ORGANISMS

(*Optional Investigation for the Study of Antibiotic Action*)

In the practice of modern medicine, the physician today has a wide range of antibiotic substances at his disposal to help him in treating various infectious diseases. Some of these are more effective than others for certain infections. Have you ever wondered where and from what these antibiotic substances are produced? In this activity you will have an opportunity to find some answers to these questions and to learn some bacteriological techniques used to obtain pure cultures and to test their antibiotic action.

Problem:

How can antibiotic producers be isolated, cultured, and tested for their inhibitory action on bacterial growth?

Materials:

Soil samples
Test organisms: *Bacillus subtilis* or other non-pathogenic cultures
Nutrient agar; two kinds; one for mycological and one for bacteriological cultures
Autoclave (or pressure cooker)
Oven
Incubator
Petri plates, twelve, sterile
Pipettes, bacteriological, twelve, 5 mililiter, sterile
Test tubes, nine, 9 mililiter water blanks, cotton plugged, sterilized
Loop, bacteriological, nichrome wire in metal handle.

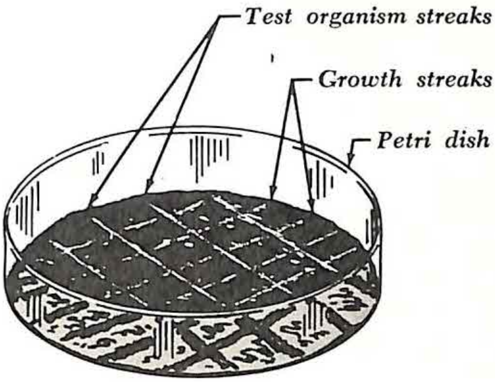
Procedure:

1. In working with bacteria, all working surfaces and materials, glassware, instruments, and media must be clean and sterilized. Glassware, such as Petri dishes and pipettes are sterilized by dry heat. Petri plates are wrapped in paper and

heated in an oven for three to four hours at a moderate temperature (350°F.). Pipettes are kept in metal cylinders with a metal cover and similarly heated in the oven. All liquids, such as nutrient agar and water, are placed in conveniently sized test tubes or flasks and plugged with non-absorbent bacteriological cotton and sterilized by steaming them in autoclave or pressure cooker for 15 minutes at 15 pounds pressure.

2. In order to isolate and study the antibiotic action of fungi, a mycological medium is used. Several of these are available from biological supply houses such as Diffco Laboratories, Inc. To study the antibiotic action of bacteria, use any good bacterial nutrient agar that restricts the growth of fungi, such as Bacto W.L. Differential Medium (B425). Prepare separately, a sufficient quantity of both media (about 50-75 mililiters of each) according to the directions on the package and sterilize the cotton-plugged flasks. Place these flasks together with the 9 mililiter cotton-plugged test tube water blanks and sterilize them in the autoclave.
3. The antibiotic producers are now ready to be isolated from the soil sample. Add sterile water to the soil in a test tube and mix thoroughly. Let stand until settled briefly and decant or pour off the liquid into an empty, sterile test tube. This is a concentrate of bacterial and fungal spores that you will use to obtain a separation of organisms by making dilutions of 1/10, 1/100, 1/1000, 1/100,000 and 1/1,000,000 in the following manner. Thoroughly mix the spore concentrate by rotating the upright test tube between the palms of your hands. Use a sterile pipette to take 1 mililiter of the concentrate and add it to a sterile 9 mililiter water blank. This tube should be marked number 1 and is the 1/10 dilution. Next pipette 1 mililiter of this solution into the second 9-mililiter water blank and mark it number 2, which is the 1/100 dilution. After mixing well this last dilution, pipette 1 mililiter of this dilution into the third test tube and mark it number 3. In a similar way, prepare the remaining dilutions. It is best to use a different clean sterile pipette at each step in making the serial dilutions in order to avoid contamination and to keep the dilutions as accurate as possible.
4. Prepare a culture plate for each dilution by pipetting 1 mililiter of each well-mixed solution into separate sterile petri plates marked 1 through 6. Lift one side of the cover just enough to insert the pipette tip. Using the same care to avoid contamination, add about 10 mililiters of melted (but not too hot) mycological agar to each dilution plate and gently swirl so that the dilution mixture and agar are thoroughly mixed. Set these plates aside to cool and harden. Use the remaining nutrient agar to pour several more plates and put aside for later use. Place the six serial dilution culture plates upside down in the incubator for 24 hours. The inverted position prevents condensation of moisture on the inner surface of the cover.
5. After the incubation period, examine the plates and select one that has several well-separated colonies. Obtain from your instructor, or ask him, how you can prepare a heavy suspension of a test organism, such as *Bacillus subtilis* or other non-pathogenic aerobe, in sterile water. Pipette 1 mililiter of this suspension onto the surface of the selected plate. Gently swirl the plate to distribute the organisms evenly over the surface and incubate for 24 hours. Examine the plate for clear rings around colonies which indicate antibiotic activity.

6. To culture the antibiotic-producing organisms, flame your bateriological loop over a Bensen burner until it gets red hot. Let cool briefly and touch the loop to the colony and streak it over a nutrient agar plate. Incubate for 24 to 36 hours. After good growth is evident, streak several test organisms at right angles to the growth streak. (see diagram to the right). Examine after a 24-hour incubation period to see if any of the test organisms are inhibited in their growth by the antibiotic producer.



QUESTIONS

1. Why is it important to sterilize all materials, glassware, instruments, and media in microbiological work?
2. What are two methods of sterilizing these various materials? Which are sterilized in dry oven heat? Why? In steam? Why? What other possible methods are used to sterilize these materials?
3. Are bacteria or fungi the better producers of antibiotics? Which produces the greater number of antibiotics?
4. From what type of soil are antibiotic producers found most abundant in nature?

Further Investigation

1. Find out how drug and pharmaceutical companies manufacture various antibiotics physicians prescribe in treating different infectious diseases.
2. In what different ways do antibiotics attack infectious agents? What is meant by selective toxicity? See Eli Lilly and Company pamphlet, "The Triad of Infection."
3. How might the strength of your antibiotic producer be compared to that of commercially available ones? (HINT: Find out about the use of Bacto-sensitivity Discs which are made by Diffco Laboratories, Inc.)

LABORATORY 46
OPPORTUNITY FOR INQUIRY: FOOD CHAINS

A food chain consists of a series of organisms with each organism serving as food for the one above it in the series. Since animals eat plants or other animals which ultimately obtained their food from plants, the base of an animal chain must be plants.

In one of the western states, there is considerable killing of small animals by firearms. The young people in this region have been led to believe that most of the animals are harmful and undesirable. Their elders often carry firearms in their vehicles to kill the predators.

Procedure:

1. List the animals you consider predators. This can include most animal species not protected by law.
2. Why would you destroy these animals?
3. What determines whether an animal is harmful or beneficial? (NOTE: The reasons children give for killing animals is that they are harmful. Biologists generally consider the animals neither harmful nor beneficial, since each organism contributes to a balance in nature.)
4. Consider each of the following animals and try to show one way that it is beneficial and one way that it is harmful:

fox	weasel
coyote	prairie dog
badger	ground squirrel
raccoon	rabbit
skunk	mountain lion

5. Which of the above animals preys on more than one of the other animals listed?
6. What would happen if their prey were eliminated?
7. What would happen to the animals if they had no predators?
8. How would the size of their population change?
9. If there were an over abundance of population of one type of animal, what would eventually happen to their food supply?
10. If there is insufficient food supply, what would happen to the health of the animals?

The following section is to be done by the entire class. Using the animals and plants, construct a food chain. Have each student in the class represent an animal or plant. Take string, cut it, and connect each organism to some other organism (another student in the class) that it eats and/or is eaten by it. For example, the fox may eat the rabbit and the rabbit eats grass, but the fox may be eaten by a mountain lion. The mountain lion may also eat the rabbit. Strings should then go from the students representing the rabbit, grass, fox, and mountain lion. Actually, three strings in this case would go to the rabbit.

grass	mouse	rabbit
beetle or other insects	rat	mountain lion
coyote	lizard	snake
fox	frog	grasshopper
badger	skunk	turtle
raccoon	weasel	tree
bird, variety	prairie dog	fish
bat	ground squirrel	water plants

When all the students have strings going between them, have them hold their hands up high.

11. What do these strings show about the interconnections of food?

Cut the strings to show what happens when different predators are eliminated from the environment.

12. What would happen if all the plants were destroyed in a big fire?
13. Would the animals be able to live very long? Why?
14. Sketch a diagram using a forest or desert environment as a food chain.

(NOTE: A basic foundation in any food chain is plants. Animals which eat plants are called herbivores and animals which eat other animals are called carnivores. What are animals called that eat both plants and animals?)

15. Which of the animals in the above list are Carnivores? Herbivores?
16. Which of the following scientific processes were involved in this invitation? Be prepared to explain your answers.

    a. Observing
    b. Classifying
    c. Using numbers
    d. Using space and time relations
    e. Communicating
    f. Measuring
    g. Inferring
    h. Predicting
    i. Formulating hypotheses
    j. Controlling variables
    k. Experimenting
    l. Defining operationally
    m. Formulating models
    n. Interpreting data

17. How would you modify this lesson to use it for the grade level you will teach?

LABORATORY 47
OPPORTUNITY FOR INQUIRY: DYNAMIC EQUILIBRIUM OF A POPULATION

A grassland biotic community began to suffer from a drought. The rabbit population, which was a part of the community, began to starve as a result. They wandered farther and farther in search of food. Some began to move up into the highlands. One weak rabbit found a small crevice caused by an earthquake in the side of a cliff. He started through it and was followed by his mate. This crack in the rocks opened into a beautiful spring-fed valley with ample grass. The two rabbits stayed in the valley and resumed their normal activity.

Coyotes of the grassland soon were also confronted with a lack of food and began to migrate as a result. A pair of coyotes stumbled into the spring-fed valley through the crevice. The rabbit population by this time had increased abundantly. The coyotes had little trouble catching some of them.

QUESTIONS

1. What would happen to the rabbit population if the coyotes had not appeared?
2. Why did the coyotes migrate later than the rabbits?
3. Would the rabbit population continuously increase in the valley? Why?
4. If no coyotes were present, would the rabbit population eventually stabilize? Why?
5. What effect would the coyotes have on the rabbit population?
6. Do the coyotes have any effect on the grass? Explain.
7. Assuming the coyotes entering the valley could mate, what would happen to the population?
8. What might limit the growth of the population?
9. How are grass, rabbit, and coyote populations related?
10. Refer to the title of this invitation. Why do you think it is so titled?
11. It has been said that one bacterium could, under the proper conditions, produce over a ton of offspring in 24 hours. Can you give some reason why this does not happen in nature?

The lesson you have just completed endeavors to give you some understanding of how an ecosystem operates. An ecosystem consists of all of the organisms that live in an environment and the relationships between them and the abiotic factors of the environment. Drought, in the above activity, was an abiotic factor that had a direct affect on the grassland. How did the ecosystem of the spring valley differ from that of the grasslands?

The above lesson also illustrates some of the principles of predation. Are there predators in the spring-valley community? Relative to numbers, would there have to be the same, more, or less preyed-on organisms as predators in the valley for the predators to survive? Are there any herbivorous predators? What are they? Herbivorous predators seldom kill their prey since they usually browse on the plants and the plants are capable of regenerating the lost parts. How about animals' predators? Do they usually just injure their prey?

Further Investigation

1. Choose some factor in the environment of the spring valley and describe what would happen if this factor were to change.
2. Outline some experiment, or demonstration children might do in class, to develop an understanding of dynamic equilibrium, predation, or an ecosystem. List the processes of science students will be involved in observing the demonstration or doing the experiment.

15

How Are Plants and Animals Adapted to Their Environment?

LABORATORY 48
HOW ARE SNAILS ADAPTED TO THEIR ENVIRONMENT?

Snails are readily available in quantity in many localities. The behavior or response to stimuli of snails may be compared to that of other animals. Snails are members of the phylum *Mollusca* and class *Gastropoda*, meaning shelled and stomach-footed animals. What kind of bodies do snails have? Do they have lungs for breathing? How do they move about? Do they leave any kind of tracks? How do they eat? What kind of environment do they and can they live in?

Problem:

What can you find out about snails that will help you understand how they adapt to their environment?

Materials:

Snails, living, any local land genera, two per student
Lettuce, fresh green
Glass plates, 6″ to 10″ square or rectangles
Sandpaper, 5 different grits
Cardboard, corrugated or masonite, scrap pieces of
Lamp, desk or microscope type
Magnets
Bunsen burner
Iron nail
Razor blades, single-edge
Salt
Sugar
Vinegar

Procedure:

1. Examine your living specimens and locate the various parts by using a diagram from a biology textbook as an anatomy guide. Does the shell spiral to the left (sinistral) or to the right (dextral)? Where is the shell attached to the snail's body so that it is able to carry the shell along with its body in motion? How does a snail survey its environment?
2. Through the use of the materials, investigate the responses of snails to various factors. What are some factors in the environment to which snails are adapted? You might try to find answers to any or all of the following questions as a start. You will probably think of many other problems you wish to investigate. Design your own experiments. As you formulate plans, ask yourself what kind of measurements could you make to obtain information for making interpretations? Record your observations and measurements.

QUESTIONS

1. How does a snail accomplish locomotion? How fast does it normally move? What is the effect of different types of surfaces? Can a snail crawl over the edge of a sharp razor blade? What would you predict for this behavior on the part of a snail in this situation?
2. What temperature do snails prefer? How could you find out? What are the results?
3. Are snails better adapted to moisture or dryness? Darkness or light? Try a simple T-maze made of corrugated cardboard or other material with different conditions at the ends of the arms. What could you use to reward a "correct" choice?
4. How do snails locate food? By sight or smell? What did you do to find this out?
5. How do snails behave when placed on a piece of glass held at various angles

from the horizontal? How does this treatment affect the speed and direction of snail travel?

6. How do snails respond in the presence of a magnet? Does the strength of magnetism have any effect?
7. How do snails react to various chemicals?
8. How do snails breathe? Can land snails breathe under water?
9. How do snails eat? Can you predict what foods they prefer? What could you do to gather information relative to these questions?
10. Outline further experiments you performed to find out other ways in which snails adapt to live in their environment.

Reference:

School Science Curriculum Project, University of Illinois, unit on Evolution of Snails, Vertebrates, and Primates. (805 West Pennsylvania Avenue, Urbana, Ill. 61801.)

LABORATORY 49 OPPORTUNITY FOR INQUIRY: NATURAL SELECTION

Charles Darwin, one of the founders of the theory of evolution, thought natural selection and adaptation were the principle mechanisms of evolution. The following experiment is described to give you some insights into the mechanism of natural selection.

Bacteria were grown in a culture in the laboratory. An investigator added a relatively weak dose of penicillin to one culture tube containing 100,000,000 bacterial cells. After a day most of the bacterial cells were dead. About ten cells, however, survived. These cells were cultured in a new tube of media until they produced over 100 million bacteria. Penicillin, twice as strong as the first dose, was then added to the tube. Again most of the bacteria died, but a few survived. The survivors were isolated, cultured, and exposed to an even stronger dose of penicillin. This process was repeated five or more times. Finally a strain of bacteria was developed that could withstand a dose of penicillin 2,500 times greater than the first dose used in the experiment.

QUESTIONS

1. What significance do you think the above experiment has for medicine?
2. How would you interpret the term "natural" selection from this experiment?
3. How could the results obtained in this experiment be used to suggest explanations for variations in color of birds, mice, and other animals in different environments?
4. How could the above experiment be used to explain the extinction of certain species of plants and animals?
5. How does natural selection serve as a creative force in evolution?
6. In what ways have man's traits been selected compared to prehistoric men?

Louis Pasteur, the great French scientist, observed sheep raised on land where sheep that died from anthrax were buried. He was walking one day in such a field and noticed an area which was particularly green. He asked the French farmer why it appeared so green; the farmer replied he had buried sheep that had died from anthrax. Pasteur knew sheep raised in an area where dead anthrax sheep were buried could be reinfected. While observing this plot, Pasteur wondered how the anthrax bacteria could reach the top of the ground to reinfect the other sheep.

QUESTIONS

1. What could carry them to the surface of the ground?
2. If you had been Pasteur, what would you have done to find an answer to this question?
3. How do you think the anthrax bacteria are adapted so they have a better chance to reinfect sheep?
4. If you were going to teach something about natural selection to your class, what would you do? Consider both plants and animals before you write your answer.

Organisms living today have been selected naturally and survive. They are adapted to their environments. These are two scientific principles. Write what you consider scientific principles to be and why you think they are important to know. It has been said one aim of the scientific enterprise is to discover scientific principles. Comment on this statement.

16

How Are Similarly Adapted Organisms Related?

LABORATORY 50
HOW DO YOU MAKE A KEY FOR CLASSIFYING ORGANISMS?

All scientific classification is based on similarity in form or *structural similarity*. Yet, differences give rise to multiple groups. In order to classify objects or things, whether they be living or non-living, you must first decide on the criteria you are going to use. Thus, in any collection or assortment of objects, you could divide (or classify) them on the basis of size, weight, color, texture, shape, form, or etc.

Problem:

How can you devise a key for classifying the members of your class? Of a collection of leaves, shells or other objects?

Materials:

Population of your laboratory class
Assortment of leaves from various trees
Sheets of carbon paper
Sheets of white paper
Electric iron
Shell assortment: clam shell, scallop shell, conch shell (univalves and bivalves)
Assortment of objects of students' choice

Procedure:

A. For identifying your classmates:

1. Make a table similar to the following in which you list the data for each member of your class.

NAME	SEX	WEIGHT	HEIGHT	EYE COLOR (Brown, blue, or hazel)	HAIR COLOR (Brown or blonde)
(Last) (First)					
	COMPLEXION (Dark or Fair)		EAR LOBES (Absent, present)		HAIR STRAIGHT? (Yes or No)

2. By arranging these characteristics into two or three alternatives, devise a key with which you should be able to identify each member of your class by name. Do this before going on to part 3 of this exercise.
3. When you have worked out your key, it will probably look similar to the following one:

1.	(3)	Hair brown (2,5)
2.	(4)	Eyes brown (6)
3.	(1)	Hair blonde (4)
4.	(2,5)	Eyes blue (6)
5.	(4)	Eyes hazel (6)
6.	(8)	Fair complexion (7)
7.	(9)	Ear lobes present (10)
8.	(6)	Dark complexion (7)
9.	(7)	Ear lobes absent (10)
10.	(14)	Straight hair (11)
11.	(15)	Weight between 150 lbs. and 240 lbs. (12)
12.	(16)	Height between 5′10″ and 6′3″ (13)
13.	(17)	Sex—male (name)
14.	(10)	Curly hair (15)
15.	(11)	Weight between 100 lbs. and 130 lbs. (16)
16.	(12)	Height between 5′3″ and 5′7″ (17)
17.	(13)	Sex—female (name)

B. For identifying various kinds of leaves:

1. Obtain 15 to 30 leaves from different kinds of trees.
2. Divide the class into several small groups of 4 or 5 students and give each group several leaves from different types of trees.
3. Obtain several carbon papers and sheets of white paper.
4. Place each type of leaf upon the carbon paper with the carbon next to the leaf. With a warm iron press firmly upon the leaf for a few seconds. Remove the leaf and place it with the carbon side down upon a white sheet of paper. Now press down firmly again with the warm iron. This will leave the imprint of the leaf upon the paper.
5. Check the leaf print for similarities and differences in the structure of the leaves.
6. Classify or group the leaf prints according to criteria that your team members select as appropriate. Compare your prints with each other and with members of other groups.
7. Work out a key for identifying any particular type of leaf included in your collection.

QUESTIONS

1. In what several ways can a set of objects be classified according to (a) color, (b) texture, (c) size, and (d) shape?
2. Upon what additional bases could a collection be divided into groups?
3. How many criteria are needed in order to reduce the problem of classification down to one individual or object?
4. How has our present system of classifying living things come into being?
5. Why do you think ancient people may have had trouble in classifying or comparing living things?
6. Why do you think Latin became the first universal language of science?
7. What information does a scientific name give you?
8. Why is the scientific name preferred above common names?
9. What advantages are there to classifying and naming living things?

Further Investigation

1. Using your collection of shells or other objects, compare and contrast them and work out a system of classification that will permit you to identify a single type of specimen.

References:

Science, A Process Approach, American Association for the Advancement of Science. Second Experimental Edition, part one, 1964, pp. 31-38.

Science for First Grade, Elementary School Science Project. Biological Supplement, Utah State University, Logan, Utah, 1964, pp. 15-27.

LABORATORY 51 CLASSIFICATION—RELATIONSHIP OF STRUCTURE AND FUNCTION

Biologists have found and named more than a million kinds of animals and over 345,000 different kinds of plants. You have learned something about a few of these in your previous studies of soil, pond, and microscopic communities. With all this diversity among life forms, it becomes important to have some system for putting organisms into groups.

Problem:

How can animals be classified into groups according to their structure? What are several criteria used in separating groups of similar animals?

Materials:

Several living or preserved specimens or embedded mounts representative of different vertebrates and invertebrates

Preserved and mounted stages in the life history of several specimens both vertebrate and invertebrate

Mounted as well as disarticulated skeletons of several vertebrates

Collection of shells or other substitutes (visual aids such as textbook drawings of different kinds of vertebrates and invertebrates or from magazines, transparencies, or photographs, 35 mm 2 × 2 slides)

Procedure:

1. Take a field trip to a zoo, museum, herbarium, or field experiment stations in your locality and observe specimens. Make written descriptions of your observations.
2. Carefully examine the external features of the various specimens noting both similarities and differences. Look at the appendages (arms, legs, toes, wings, tails, fins, tentacles, mouthparts, eyes, etc.) and type of skin covering. Record your observations in a brief description for each specimen.
3. Look at your living specimens and compare their methods of locomotion. In what kind of habitat would you expect to find each of these specimens? Why? Feel the live animals. Are they warm, cold, wet, dry, or slimy? Which of your specimens are cold-blooded? Warm-blooded? How do they breathe? Do they have lungs, gills, or a moist skin? What kind of food do these animals eat? How does this help you classify them? What is meant by carnivorous, herbivorous, and omnivorous? Which of your specimens have these various diets?
4. Examine the life history mounts. How do the eggs of the several specimens differ? Sketch the different types of eggs you observe. What is meant by oviparous, ovoviviparous, and viviparous? Which of your specimens reproduce in these different ways? How do these animals care for their young? The newborn of which of your animal specimens feed on milk from their mothers? What other methods of feeding their young do your animal specimens use? Does knowing the methods of feeding the young help you classify animals in different groups?

5. Examine the mounted skeletons of various specimens. Also, look at disarticulated skeletons of these same specimens, if possible. Look at the backbones of each; compare and contrast them. What are the individual bones that go to make up the backbone called? Note the similarities and differences in skeletal structures of the various specimens. Look at the jaw bones in particular.
6. Do all of the specimens you have examined have backbones? What types of animals do not have backbones? What is an exoskeleton? Can all animals be classified into one of these two groups?

QUESTIONS

1. Why do biologists find it necessary to classify animals into different groups?
2. What advantages are gained by doing so?
3. As an elementary teacher, your students will ask you the names of living things they find on field trips or bring to class. How does the study of classification aid in finding the names of these organisms?
4. How could you place the animals that have backbones into different groups? What are the several characteristics that differentiate these animals from each other?
5. How could you place the animals without backbones into different groups? What are the several characteristics that differentiate these animals from each other?
6. What scientific processes are involved in classifying?
7. Do you think allied sciences, like physics and chemistry, can be of help in classification of plants and animals? How? Explain.
8. Has man or society changed the natural taxonomic position of domesticated species by using the animal or plant in a specific way over a period of years?
9. Do reproduction and gestation periods aid in classifying the larger units or smaller units?
10. Can you give an example of *taxon* (unit of classification) known by a common non-scientific term? How about *snakes* for *Reptiles* or *birds* for *Aves*?
11. If you were to examine prepared slides of blood from a chick, frog, reptile, rat, or man, could you use your observations to help you in classifying these organisms if found in a scientific key? If so, how?
12. How, if in any way(s), does climate and geography influence classification?
13. It has been said that if you know insects have 6 legs, you know over 900,000 facts. Explain why this is so.
14. A cheetah is a mammal. Without looking in any book, list as many facts about it as you can. (HINT: Remember, you are also a mammal.)

Further Investigation

1. Using the data you have recorded for your observations of different types of animals, construct a simple two-way (or dichotomous) key, as you have learned in the previous lesson, that will separate the several specimens in a single group of vertebrates, such as fishes, amphibians, reptiles, birds, or

mammals. This could be an extended project for small groups over a many-class session.

2. Devise a similar procedure appropriate for examining and classifying the various types of plants.
3. Find out about the life cycle of wheat rust and barberry. What is their parasite-host relationship? How are such relationships used in classification schemes?
4. What additional questions do biologists ask about the internal anatomy of animals that help them in problems of classification?
5. Find out the various systems of classifying animals and plants that have been used since the days of Aristotle and later Carolus Linnaeus on down to present day.
6. Specialists in classification are known as taxonomists. There are two kinds of taxonomists—splitters and lumpers. What is meant by these terms and of what significance is this issue to biology?
7. What is meant by a "species?" Do biologists have a satisfactory definition for this term? If not, what are some of the issues at stake?

Note: Classification is an important scientific tool that aids man to store a tremendous amount of knowledge in his brain. Piaget has found children ages 7-11 are able to construct class and relation concepts. This ability of the child to form class and groups enables him to expand his mental activity greatly. It is very important for the child that he have opportunities to develop this ability during this period of his mental development. Activities to involve the child in classifying should, therefore, be encouraged in all elementary grades. The primary grades would involve simple classification activities when the children might discover characteristics of only one group of animals or plants. In grades 5 and 6 the child should be able to do an activity similar to the one you have just completed in this lesson.

See the film "Putting Animals in Groups" produced by *International Film Board of Canada*, 13 min. color.

17

How Does Man Modify His Environment?

LABORATORY 52
OPPORTUNITY FOR INQUIRY: WATER POLLUTION

A boy caught several small fish in a private pond fed by a mountain stream in the mountains. He put the fish in a large container with some water and brought them to his school. He wanted to put his fish in several unused aquaria in the classroom. He needed to fill these aquaria with water. Someone told him he should use water from the stream near his house in preference to tap water. His teacher did not know if this was a good idea or not, so the class decided to do an experiment to determine whether the water made any difference.

1. Before reading any further, outline the experiment you would do.

   The class collected some water from the stream in one aquarium and water from the faucet in the other aquarium. The boy put two fish in each aquarium and left the remainder in the mountain water he had collected.

2. Write your hypotheses as to what would happen to the fish.

   The fish in the stream water soon began to act unusual. They started to swim faster and turn on their sides in an odd manner. Within a few hours they were floating on their sides on top of the water.

3. Why do you think this happened?
4. Why don't you think it happened with the fish in the tap water?

   After a few hours the fish in the tap water began to behave in an unusual manner. The boy became concerned about this. He did not want all of his fish to die, and yet he wanted to have a definitive answer about the tap water.

5. Write what you could do in this situation.

   He decided to take one of the fish out of the tap water but leave the other one. When he took the fish out, he held it by the tail and shook it a little. He washed the tap water off the fish with mountain water and transferred it to the mountain water container. The fish looked sick for a day, but lived.

6. Write what can be concluded from this information.

   The fish, however, that remained in the tap water died.

7. What can be concluded about the tap water?
8. What is added to tap water so humans do not become ill from contaminants and germs in the water?
9. Does this chemical harm you?
10. Do you think it would harm fish? Explain.
11. How could you do an experiment to tell for certain?
12. What do you think was in the stream that may have caused the death of the fish? The water in the stream came from the same mountains where the fish were collected. Is it still the same water? Explain.
13. What may be added to the water in a stream as it passes through a city?
14. After performing the above experiment, the boy remembered that no one fished the stream near the city. What does this suggest about the stream?
15. How could the water be changed so that fish could once again live in the stream near the city?

Note: This lesson develops concepts related to pollution of streams and how pollutants can kill animal life. Concepts related to the purification of drinking water by the use of chlorine are also introduced. It must be noted, however, that chlorine is added to water in such small amounts that it does not harm human beings. However, fish are usually more sensitive to this chemical and pollutants would kill them. This lesson could be adapted to introduce children to the problem of pollution in their own community.

The children should be encouraged to find out what is being done to control pollution of the streams in their community and state. Members of the class should also be encouraged to find out what is being done to control air pollution.

Tap water, if poured into a large container and left for 24 hours, would probably be usable for fish in an aquarium since most of the chlorine gas would escape from the water.

Design a lesson to develop concepts relating to air pollution. Consider the problems of smog, fog, and in certain localities industrial wastes, such as smoke or obnoxious odors from factories and packing plants. What if anything can be done about these problems?

Refer to Laboratory 46 for a list of scientific behaviors. Which of these listed are involved in this invitation? Explain your answers.

Further Investigation

Read and report on the article "Water Pollution" by Donald J. Reesh, in *Science and Children*, November, 1963, p. 13.

18

How Do Environmental Changes Affect Man and Other Organisms?

LABORATORY 53
MODIFICATION OF RESPIRATION AND BREATHING

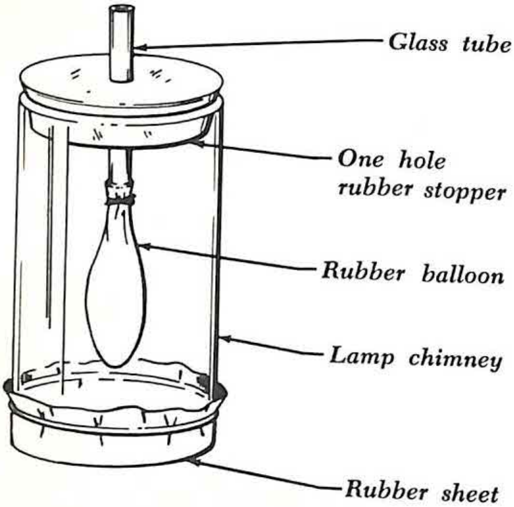
How long can you stay under water? Why can't you breathe under water? Why can some animals live in water while man and others cannot? For all living things there are three essentials to external breathing: (1) oxygen-containing medium (air or water), (2) a membrane through which diffusion of gases from this medium enters the cells, (3) the blood, tissue fluid, or cytoplasm.

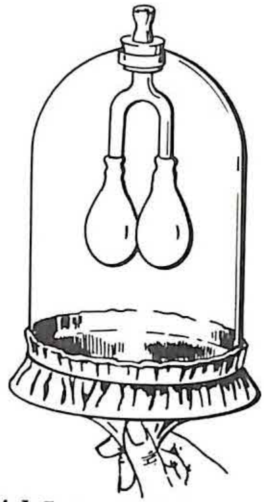
Problems:

How does man breathe? How much air does man breathe? How fast does man breathe? What does man exhale? What happens if man breathes too much air?

Materials:

Model of lungs—made of a gallon jar from which bottom is removed and replaced by a piece of sheet rubber; fit a one-hole stopper of rubber with a glass tube mounted inside the jar to which a balloon is fastened at the end. (See diagram.)

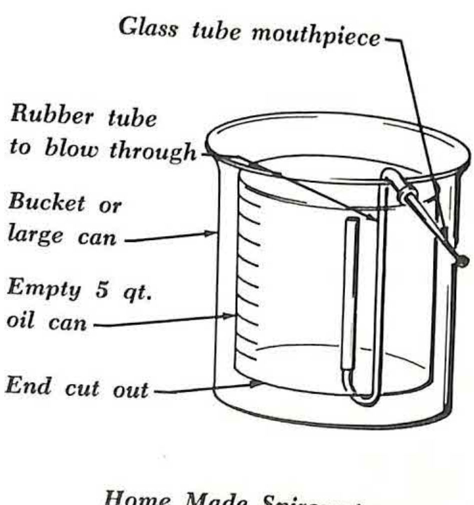




Commercial Lung Demonstration Model

Spirometer—either commercial or home-made; consisting of an inverted graduated cylinder fitted over a similar cylinder filled with water; a tube filled with a glass tube mouthpiece which passes up through this cylinder; as air from the lungs enters the tube, it causes the inverted cylinder to rise and the amount of air entering it can be read directly from the scale. The mouthpiece is sterilized in 70 per cent alcohol solution before use. (See diagram of spirometer.)

Mirrors, small pocket size
Limewater
Alcohol solution, 70%
Soda drinking straws or glass tubes
Paper bags, no. 8 and no. 12
Cloth measuring tape
Torso model of human body or chart of respiratory system
Prepared slides of alveolar tissue
Microscope or microprojector
Clock or watch with second hand



Home Made Spirometer

Procedure:

Work in pairs of similar sex as directed by instructor.

A. To find out how man breathes you will investigate the structure and function of your breathing apparatus.

1. Using either a torso model or chart of human respiratory system, identify the various parts in the anatomy of the respiratory system. Locate the chest cavity, lungs, diaphragm, ribs, etc.
2. Examine a cross-section slide of prepared tissue under the microscope or microprojector. Identify the *alveoli*, and, if possible, capillaries associated with the alveoli. Sketch a portion of tissue showing an alveolus, alveolar duct, pulmonary vein, and capillaries.
3. Using the lung demonstration model, pull down on the rubber sheet covering the bottom of the jar. What do you notice happening to the balloons inside the jar? What do you think will happen if you push up on the rubber sheeting? Why does the balloon change shape? How does the lung model differ from your body thus giving you an incomplete picture?

B. To find out how much air man breathes, you will use the spirometer. While holding the nose, practice breathing through the mouthpiece (after you have first sterilized it in the 70 per cent alcohol solution) into the spirometer. Have your partner face away from the spirometer. Obtain readings under each of the following conditions and record your results.

1. *Tidal Air.* Make a normal inspiration from the air in the room and then exhale it (a normal expiration) into the spirometer. An assistant may read on the scale the volume of air exhaled into the cylinder. Repeat a few times and get an average and put results in the following table.
   (a) Define tidal air.
   (b) Why is it difficult to obtain a correct value under the conditions of the experiment?
2. *Supplemental Air*, (measured). Make a normal expiration into the room, and then exhale all you possibly can into the cylinder. This amount will be your supplemental air. Repeat a few times and get an average.
3. *Complemental Air*, (measured). Make the deepest possible inspiration from the air in the room and then exhale into the spirometer, stopping at the end of a normal expiration. This amount will contain the complemental air, plus the tidal air. From this reading, subtract your tidal air as found in (1) and the remainder will be the complemental air. Repeat as above for an average reading.
   (a) Define complemental air.
4. *Vital Capacity*, (measured). Make the deepest possible inspiration from the air in the room and then the greatest possible expiration into the cylinder. This will give you the complemental air, plus the tidal air, plus the supplemental air, which totals the vital capacity.
5. *Vital Capacity*, (calculated). Add the results obtained from (1), (2), and (3). Does the sum equal the reading obtained in (4)?
6. *Complemental Air*, (calculated). Calculate complemental air from the readings obtained in (1), (2) and (4). How do you do this?

Sample Table

MEASURED LUNG CAPACITIES

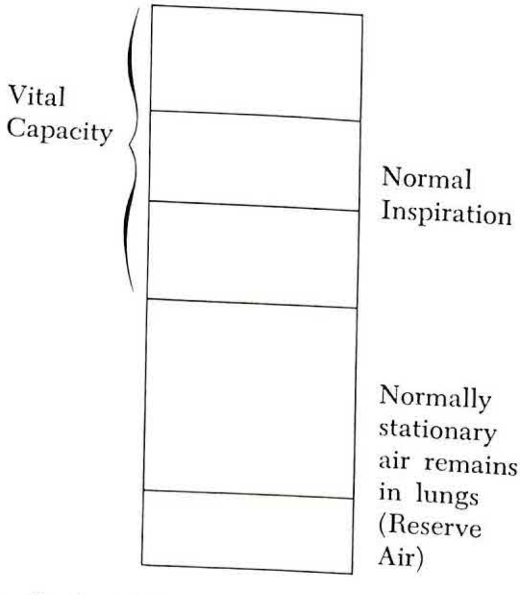
Condition	Cubic Inch*	Cubic Centimeters*
1. Tidal air	(1)______	______
2. Supplemental air, measured	(2)______	______
3. Complemental air, measured	(3)______	______
4. Vital capacity, measured	(4)______	______
5. Vital capacity, calculated	(5)______	______
6. Complemental air, calculated	(6)______	______
7. Vital capacity, average for your height	(7)______	______

*I CUBIC INCH = 16.38 cubic centimeters

7. Determine your exact height and from the chart posted in the laboratory find the normal vital capacity average for your height.
8. *Daily Pulmonary Ventilation.* Have a fellow student count the average number of your respirations per minute, while breathing normally. Calculate the total volume of air respired during the 24 hours using the average tidal air value obtained in the chart above. (This assumes that all conditions are fixed during the entire period.)
9. Draw a diagram similar to the diagram below and record in the proper spaces the measured volumes from your table above.
   (a) What is meant by residual air?

Chest Measurements

1. At rest ______
2. After normal inhalation ______
3. After forced inhalation ______
4. After forced exhalation ______



   (b) With a tape, measure your partner's chest (1) at rest, (2) after normal inhalation, (3) after forced inhalation, (4) after a forced exhalation. (Summarize your results by completing the diagram.)

C. To determine how fast man breathes, you will investigate the rate of respi-

ration or breathing both at rest and after a short period of exercise. Have your partner close his mouth and hold a mirror near his nose. Watch the mirror and count how many times your partner breathes per minute. You will notice condensation on the mirror with each breath. Record the rate of breathing at the end of the first, second, and third minutes. Why do you think we should determine the rate over a three-minute period rather than just one minute? Now, have your partner run or jump in place for about a half minute and again count his rate of respiration at the end of the first, second, and third minutes. Record the results in a table.

D. To find out what man exhales, first have your partner hold a small mirror near his nose. Each time he exhales you will notice that a little moisture appears on the mirror. From where does this moisture come? Why does it collect on the mirror? From this evidence, in what form is the gas being exhaled? What do you think this gas is? You may remember that air is composed of about 79 per cent nitrogen and a little over 19 per cent oxygen. What happens to the nitrogen? The nitrogen in the air is not used in breathing, so the same amount is both inhaled and exhaled. Next, obtain some limewater in a small jar or glass and a soda straw or glass tube. Exhale air from your lungs through the limewater. What happens as you continue to exhale air into the limewater? When carbon dioxide gas is added to limewater it causes a milky precipitate to be formed. The chemical reaction is as follows:

$$Ca(OH)_2 \quad + \quad CO_2 \longrightarrow H_2O \quad + \quad CaCO_3 \downarrow$$

(Limewater) + (Carbon dioxide) forms (Water) + (Calcium carbonate)

What two things have you learned about what man exhales?

E. To find out what happens if man breathes too fast, have your partner sit and breathe with his mouth open as deeply as possible for exactly one minute. Time the person. How does your partner respond to this exercise? Ask him how he feels. Why do you suppose he feels dizzy after breathing in this manner?

How long can you hold your breath after breathing normally? After a forced expiration? After breathing deeply 3 or 4 times? After exercise?

Wrap the open end of a paper bag around a one-hole rubber stopper with a glass tube mouthpiece. Hold your nose shut and breathe into the bag through the mouthpiece for a few minutes. Breathe and re-breathe the air in the bag and have your partner count your respiratory rate as you do. Is there any change in rate? If so, why?

QUESTIONS

1. Draw a diagram of the human respiratory system and label the lungs, diaphragm, chest cavity, and other parts.
2. Summarize the changes that take place in the size, shape, and position of the lungs, diaphragm, and rib cage in normal breathing by making sketches of these parts after exhalation and inhalation.

3. What is the difference between "external respiration" and "internal respiration?"
4. How close is the blood stream to outside air (in the lungs)?
5. What effect does exercise have on the rate of respiration?
6. What gas do we need from the air?
7. What does man exhale?
8. What is meant by hyperventilation? What is the effect of hyperventilating the lungs?
9. How does this affect the body?

Expected Behavioral Outcomes:

You have not only learned many facts about the respiratory system, but you have also used several processes of investigating, including observing, recording, measuring, inferring, predicting, etc.

Further Investigation

1. *Marey Tambour, Pneumograph, and Kymograph.* Obtain a pneumograph, which consists of a strong spring enclosed in a rubber tube. The Marey Tambour is a device that magnifies and records on a kymograph record changes in pressure within the pneumograph. Fasten the pneumograph snugly around your partner's chest, keeping the T-tube between pneumograph and tambour open while adjustments are being made. Now, close the T-tube and, with your partner facing away from the kymograph drum, make tracings under the following conditions:

   (a) Normal breathing
   (b) Laughing
   (c) Talking
   (d) After exercise

   Label the tracings, shellac, and dry the records.
2. *Porter Respiration Scheme.* Obtain a Porter Respiration Scheme if available and study the changes of pressure which occur in various parts of the respiratory system under different conditions which you may simulate. What is meant by pneumothorax? The Porter Respiration Scheme shows pressures in various parts of the respiratory system.

QUESTIONS

1. What is meant by apnea, hypernea, dyspnea, polypnea? Of what medico-legal importance is "minimal" air?
2. What relation does the pigment hemoglobin of the blood bear to the process of respiration?
3. What is the role of carbon dioxide in the respiratory process?
4. What are tonsils and adenoids? What are several common diseases of the respiratory tract? Why should a person breathe through their nose? What purpose do the sinuses serve?
5. What are bends? How are they caused?
6. What effect does mountain climbing have on the respiratory system?

7. How do lower animals (protozoa, coelenterates, flatworms, earthworms, clams, sponges) obtain oxygen?
8. How is oxygen obtained by insects? Algae? Fungi?
9. How does a flowering tree or plant get oxygen?
10. Find information about recent medical advances in surgery using the artificial heart and lung machines.

LABORATORY 54 MODIFICATION OF CIRCULATION—HEART AND BLOOD

Students commonly exercise during such periods as recess on the playground or in the gymnasium. You may have noticed after such periods that you feel considerably warmer and your heart beats faster.

Problem:

How does exercise affect the rate of heartbeat? Is there a difference for the rate of heartbeat between men and women?

Materials:

Paper and pencil or chalk and chalkboard
Stopwatch or watch with a second hand
Stethoscope (if available) and sphygmomanometer
Live frog or goldfish
Physiology reference textbooks

Procedure:

1. Work in teams or as directed by the instructor. Record the results of men and women separately, or, if working with a large class, take a proportionate sampling of both sexes—perhaps a third of each group.
2. First, determine the average rate of heartbeat of men and women while sitting at desks by asking each person in your team to take his pulse in his radial artery for one minute. This artery is found just behind the wrist on the thumb side of the forearm. The pulse can be taken by placing the index and middle fingers on the wrist just behind the thumb. When the pulse is located, start counting until exactly one minute has passed. Record the various pulse rates for men and women separately in two tables similar to the following:

	SUBJECT (Men or women)	PULSE RATE (When seated)	PULSE RATE (After one minute of exercise)
1.			
2.			
3.			
4.			
5.			
6.			

3. How can you find the average pulse rate when seated? What can be concluded from the data you have gathered?
4. Determine the average rate of heartbeat of men and women after "running" in place (or stepping on and off a chair) for about one minute. Record this information in the appropriate columns of the tables and determine the average heartbeat rate for men and women in your team.

QUESTIONS

1. Compare the average heartbeat rates of men and women both before and after exercising. What do you conclude from your data?
2. How do the heartbeat rates of individual members of the class vary?
3. What are the fastest and slowest rates?
4. What is the "normal" or average rate of heartbeat for men and women of a given age as determined by medical statistics? Consult a good physiology textbook such as Zoethout and Tuttle, C. V. Mosby Co., St. Louis, Missouri.
5. How does this vary with age and sex?
6. How does the heartbeat rate of athletes compare to non-athletes? Why is this so?
7. If you were going to report your findings to a scientific meeting, what would you do in repeating the above procedure in order to insure more accurate results?
8. In doing this activity, what reasons can you see for individual differences manifested in these observations?

Further Investigation

1. What factors, other than exercise, change the rate of the heartbeat? How do these factors affect the pulse rate?
2. Obtain a stethoscope and listen to the heartbeat sounds of either yourself or a lab partner. What causes these heartbeat sounds?
3. If a sphygmomanometer (blood pressure measuring instrument) is available, find out how to measure the diastolic and systolic blood pressures. What should these blood pressures normally be for persons your age? What causes variations in blood pressure?
4. Investigate the circulation of blood in the capillaries by looking at the web of a frog's foot or tail of a goldfish or polliwog under a microscope. For a description of how to prepare the frog or fish for viewing under the microscope, consult any standard biology methods textbook. Can you see the ebb and flow of blood with each beat of the heart?
5. Read about and write a report on the discovery of the circulation of blood by William Harvey and determine how he reasoned its existence without the aid of the microscope.
6. What is the role of mathematics and quantitative reasoning in biology as evidenced in Harvey's investigation? How is mathematics used in modern biology?
7. Investigate the typing of blood for donors and recipients. If possible, determine your blood type by actual tests for A, B, O series and Rh series.
8. Prepare a slide of your blood, stain it with Wright's stain according to procedure

in the *Sourcebook* by Morholt, Brandwein, and Joseph, and examine it under a microscope. What are the various parts found in whole blood?

References:

1. Mark Graubard, *Circulation and Respiration.* The Evolution of an Idea, Ideas in Science, A Harbinger Book, Harcourt Brace & World, Inc., New York, 1964.

2. Evelyn Morholt, Paul F. Brandwein, & Alexander Joseph. *A Sourcebook for the Biological Sciences.* Harcourt, Brace & World, Inc., New York, 1958.

LABORATORY 55
THE EFFECTS OF STIMULANTS AND DEPRESSANTS ON AN ORGANISM

Materials:

Daphnia
Microscope
Microscope slides, cover slips
Solutions: tea, coffee, alcohol, unknowns (provided by instructor)

Procedure:

1. Obtain some *Daphnia* (water fleas) from pond water or a culture maintained in the laboratory.
2. Take some small broken pieces of cover glass and place them near the center of a slide. These are used to hold up the cover slip so that it will not crush the *Daphnia.* Using a pipette place a drop of water with a *Daphnia* on it in the center of the slide near the broken pieces of the cover slips. Cover with a cover slip. Look at the *Daphnia* under low-power magnification. Determine the normal heartbeat for your organism. Consider before doing this how you determine with any degree of certainty the heartbeat rate. Record your data.
3. Obtain 5 cubic centimeters of each of the following solutions from stock: tea, coffee, alcohol, and unknowns marked 1 and 2. Test the effects of these chemicals on *Daphnia* by starting with one drop of one of these solutions mixed with one drop of water. Repeat this procedure for each of the other solutions. Describe the procedure you used and report the information and data.
4. Design and perform an experiment to determine how the heartbeat in the *Daphnia* changes with an increase in chemical concentration. Outline your experimental procedure and data.
5. State what should be done to obtain better results if the above experiment were to be repeated. Keep in mind that any experiment may have errors.
6. What relevance does this laboratory investigation have for man?
7. State any further experiments suggested by this laboratory activity.

The purpose of this laboratory activity was to show that the rate of basic life processes can be increased or decreased by means of chemicals. In your laboratory

experimentation you found chemicals could increase (stimulate) or decrease (depress) the heartbeat rate. Chemicals that increase the rate are called stimulants, and those that decrease are called depressants. The chemicals used in the activity are not naturally found within the organisms. You have already studied chemical regulators—hormones—found naturally in the organisms. How do they differ from stimulants and depressants in their effect on animals?

19

Man's Senses

Did you know that we live in an environment of electromagnetic waves of different frequencies? In earlier laboratory studies you learned how different scientific instruments detected various forms of energy and something about the nature of light and related forms of energy. You know, for example, that you cannot "hear" a radio broadcast without the aid of a radio receiver. You know also that man, among the animals of the world, is relatively insensitive to certain stimuli. For example, sounds lower than about 20 vibrations per second or higher than about 20,000 vibrations per second cannot be detected by human ears although dogs can detect these higher frequencies. Man's sight is similarly limited to a narrow band of the electromagnetic spectrum called "visible" light consisting of wave lengths ranging from 3900 A° to 7800 A°. An A° (Angstrom unit) is a very short length of 1/100,000,000 centimeter. Your eyes perceive these wave lengths as gradations of colors red to violet or, in combination, as "white" light. Color vision is somewhat of a mystery since a good explanation and understanding of this phenomenon still eludes the world's best scientific minds. The senses of smell, taste, and touch are likewise very complex.

In spite of a few limitations, nearly everything man learns comes through

his senses. You may have wondered whether what we observe with our senses is real or whether it is merely representative or symbolic of reality. What do you think are some possible answers to this question?

In the following investigations of man's senses, work in teams of two unless otherwise directed.

LABORATORY 56
HOW IS MAN'S EYE SENSITIVE TO LIGHT?

Problem:

How is man's eye sensitive to light?

Materials:

Model or charts of eye
Microscope slide of cross section of eye showing retina tissue
Fresh or preserved beef or sheep eye
Visual acuity test charts (Snellen or other)
Astigmatic test, Greene's
Color blindness test charts (Ishihara, Dvorine Pseudo-Isochromatic or other)

Procedure:

1. Consult a model or chart of the human eye and locate the various parts of *eye anatomy*. If available, dissect a fresh or preserved beef or sheep eye. Making a drawing of the human eye and label all of its parts properly. Examine a microscope slide of eye nerve tissue and of the retina.
2. Put a pencil in a glass filled about two-thirds full of water. What do you notice as you look at the pencil from the side of the glass? How can you explain what you see?
3. Have your partner sit with eyes closed and covered with his hands while facing a source of bright light as from a desk lamp. After one minute have him uncover and open one eye. What do you observe about the pupil of the eye? How can you explain what you see?
4. Sit and stare briefly at a bright light bulb. Look away at a blank inside wall. Observe the after-image of the light bulb until it disappears completely. How does the after-image change before it disappears? How can you explain what you see?
5. Have your partner sit facing you and cover one of his eyes with his hand. Temporarily turn your back to your partner and touch both of your index fingers together. Now, by keeping them in an imaginary straight line extending away from your chest, move one index finger toward, and the other away, from your chest so they are about 18 inches apart. Turn and face your partner again. Line your two fingers up with his eye and ask him to tell you to stop moving your fingers when he thinks both fingers are at the same distance from his one

open eye. Ask him to uncover his closed eye and look at his estimate. How does binocular vision enable you to judge distance more accurately? Explain.

6. Have your partner look at an object twenty feet or more away. Notice the position of his eyeballs. Now, have him shift his gaze to an object, such as a pencil held about ten inches from his face. How does the position of the eyeballs change as his gaze shifts from a far to a near object? Explain.
7. Have your partner sit with his hand toward a window and fix his gaze at an object twenty feet or more away. Observe his pupils. Now have him shift his gaze to a pencil held about ten inches from his face. Watch his pupils carefully as his gaze shifts from a far to a near object. Do the pupils change any in size when the shift in vision-distance is made? If so, how?
8. Notice the black cross and dot in the figure below.

Close your right eye and hold the figure about a foot and a half from your eyes directly in front of your face while looking at the cross with your left eye. Now, slowly move the figure closer to your face. The dot will disappear from your field of vision at a certain distance. Notice that as you move the figure closer to your face the dot reappears. How can you explain what you do not see? Using your right eye, repeat the experiment, and concentrate upon the dot instead of the cross. Do you get results similar to those for your left eye? Explain.

9. If your partner wears glasses (this includes contact lenses as well), have him remove them. Use a Snellen, or other, chart illuminated with 200 watts of light and locate the testee exactly twenty feet from the chart. Test each eye separately by having the testee hold a card over the unused eye. Watch the testee's eyes, not the chart. Record results for each eye. Indicate which letters or numbers the testee can read at twenty feet *without squinting*. What is 20/20 vision? Repeat the test with eyeglasses on.
10. Use color blindness test plates. Follow the directions furnished with the plates to test the type and degree of any color blindness. What causes deficiences in color vision? How might color blindness be a disadvantage or hazard not only to the deficient person but to others also?

QUESTIONS

1. How are different malfunctions of the eye sometimes corrected?
2. What different theories of color vision are there?
3. How do the rods and cones in the retina of the eye function in vision?

Reference:

Note: Write to the National Society for the Prevention of Blindness, 1790 Broadway, New York City, New York and ask for a catalog of publications. This agency has many valuable materials for teaching and learning about care of eyes.

LABORATORY 57
HOW IS MAN'S EAR SENSITIVE TO SOUNDS AND BALANCE?

Problem:

How is man's ear sensitive to sounds and balance?

Materials:

Model or chart of human ear
Microscope slide of organ of Corti
Cloth towels or handkerchiefs for blindfolds
Watch
Tuning forks
Stethoscopes

Procedure:

1. Use models and charts to locate the various parts of the ear: outer, middle, and inner. Label a diagram of the ear with all of the parts properly.
2. Have your partner close his eyes and plug his right ear with the index finger tip. Find the greatest distance that the ticking of a watch can be heard while holding it opposite the left ear. Record the distance. Repeat and record the distance for the right ear by using the same watch.
3. Wash and dry the handle of a tuning fork. Set the tuning fork in motion by tapping the prongs against the palm of the hand. Hold the fork close to the ear until the sound can barely be heard. Now, bite the handle of the fork tightly between the teeth. Can you hear the sound? Explain.
4. Try placing a vibrating fork on top of your head. From where does the sound seem to emanate? Plug one ear with a finger tip and again place a vibrating tuning fork on top of the head. From where does the sound seem now to emanate? How can you explain these results?
5. Place the earpieces of a stethoscope in your ears. Pinch the tube that leads to one ear. Bring a vibrating tuning fork close to the stethoscope bell opening and listen to the sound until it becomes nearly inaudible. Now, open the pinched tube to the other ear. What do you hear? Explain.
6. Use a cloth towel or handkerchief to blindfold your partner's eyes. Have your partner raise his left foot off the floor and balance on his right foot for fifteen seconds while you time him. Instruct your partner that he may move the raised leg, use his arms, or shift the leg on which he is standing as long as he does not touch the floor with the raised foot. Allow him three trials on one foot and then repeat the test by having him balance on the opposite foot. What factors might interfere with an individual's ability to balance?
7. Use a revolving seat stool for this experiment. Sit on the stool, bend your head slightly forward, and close your eyes. Have your partner rotate you about ten complete turns to the right at the rate of about 2 rotations per second. Stop,

open your eyes, quickly look straight ahead, and try to walk in a straight line. Describe the sensation you experience. What might cause this sensation?

8. Hold your nose and close your mouth, then swallow. Describe the sensation you experience. Between what two cavities do the Eustachian tubes connect? What happens if there is not equal pressure on both sides of the ear drum?

QUESTIONS

1. What is a decibel? How is it measured?
2. How are different malfunctions of the ear sometimes corrected?
3. What theories of hearing are there? Which of these do you prefer? Why?

Reference:

NOTE: Write to the Sonotone Corporation, Elmsford, New York and ask for their charts and pamphlets about care of ears and helping the partly deaf.

LABORATORY 58
HOW IS MAN'S NOSE SENSITIVE TO ODORS?

Problem:

How is man's nose sensitive to odors?

Materials:

Powdered cinnamon Vanilla Salt Flour Paste sticks or wooden splints Squares of stiff paper	Mix equal parts of cinnamon with flour. Add water until mixture is of paste-like consistency. Do the same with salt, flour, and water. Prepare a third mixture using equal parts of vanilla, and water with enough flour to make a paste.
Water Alcohol White vinegar Food coloring Peppermint extract Lemon extract Small bottles with caps	Divide vinegar into two equal parts. Add some food coloring to one part. Add some food coloring to an equal quantity of water. Pour colored water, plain water, alcohol, white vinegar, colored vinegar, lemon extract, and peppermint extract into small bottles and screw caps on tightly until ready for use.
Toast (burned) Bacon, fried A lemon An onion An orange	Cut lemon, onion, pepper, orange, and chocolate into pieces and place all these items into separate paper bags. Label the bags by numbers or letters.

A green pepper
A square of baking chocolate
Small paper bags

Three empty glass bottles
Perfume, same color as lemon extract
Gasoline, small bottle

Allow odor of perfume to fill one bottle. Leave second bottle odorless. Pour remainder of perfume into third bottle.

Procedure:

1. Use models and charts to identify and locate the parts of the nose, nasal passageways, and associated structures such as sinuses. Label a diagram of these regions with all of its parts properly.
2. Examine a microscope slide of olfactory tissue. Locate and describe the odor sensitive cells. Draw and label some of these cells.
3. Divide the class into three groups. Give each person in the first group a sample of the cinnamon paste on a paper square. Similarly give each person in the second group a sample of the vanilla paste, and each person in the third group a sample of the salt paste. Ask such questions as: What color is your substance? Does each group have a different color? Can you find other differences between the substances on the paper squares? How can you tell?

   Sight shows you the colors are different. Your sense of hearing does not help you to distinguish between the samples. Tasting strange substances may be dangerous, so you cannot use your sense of taste. The texture of the different pastes is the same, so your sense of touch cannot help to distinguish between the samples. Smell your sample as well as those of other group members. Do all the substances smell the same? How do they differ? Can you describe the odors? Which substance had the strongest odor? The weakest? No odor?
4. Pass small bottles of alcohol and plain water around the class. Ask: Do you think these bottles have the same liquids in them? What can you do to find out if the liquids are the same? Caution the class members to use care in smelling strange liquids. Have them remove the cap and then gently waft their hand over the opening toward the nose so as to dilute the odor of the liquid in the air. Do not hold the bottle close to the nose, only close enough to detect any odor. After each person has smelled the liquids in both bottles, ask: Do they smell the same? Repeat the process using the peppermint extract and colored water; then the lemon extract and perfume or colored water of the same color. After these experiences ask: Do things that look the same always smell the same?
5. Pass small bottles of white and colored vinegar around the class. Ask: Do you think these bottles have the same liquids in them? Do they look the same? How are they different? Aside from their odors, how can we tell they are different? After these experiences you should realize that although the two liquids smell the same and are both called vinegar, one sample contains something that the other one does not. Repeat the process by having students compare the odors of cinnamon paste and cinnamon candy, peppermint extract

and peppermint leaf or candy, and the lemon extract and lemon. After these experiences, ask: Do things that do not look the same sometimes smell the same?

6. Pass several small paper bags each containing a single substance around the class. The bags may contain pieces of burned toast, fried bacon, lemon, onion, orange, pepper, and chocolate. Ask the class to try to identify the contents of each bag by using the sense of smell alone. Do not look at the contents! Ask: Can substances be identified by their odors alone?
7. Pass two kinds of bottles around the class members. Both kinds of bottles appear to be empty, but one kind has the odor of perfume. Tell the class that there is a secret about one of the kinds of bottles and ask if they can identify it. This process may be repeated with two empty bottles, each of which has a different odor or with bottles of different colors that have like odors. This may be done independently or as a follow-up exercise.

QUESTIONS

Ask and discuss the following questions, but do not allow the discussion to become a testing session.

1. How can your sense of smell help you?
2. For what can you use your sense of smell?
3. Do all substances have odors?
4. How do substances differ from each other?
5. Do all things that look the same smell the same?
6. Do things that smell the same also look the same?
7. What safety measures must we use when smelling strange substances?
8. What are the "vibration" and "radiation" theories of why things smell?
9. What is a new theory of smell proposed by Dr. J. E. Amoor, University of California, Berkeley?
10. How do these three theories differ from each other?
11. How does Amoor's theory explain what are seven possible smells?
12. What effect does sniffing gasoline have on your sense of smell?

Reference:

J. E. Amoor, "What's New in Sight, Sound, and Smell?", *Current Science*. Vol. XLIX, No. 22 (March 2-6, 1964), pp. 1-3.

LABORATORY 59
HOW IS MAN'S TONGUE SENSITIVE TO TASTES?

Problem:

How is man's tongue sensitive to tastes?

Materials:

Solutions: 5% sucrose
1% acetic acid
1% salt (NaCl) sol.
0.001% quinine
Cotton-tipped swabs

Procedure:

1. Consult a model or chart of the tongue. Label a diagram of the tongue and all of its parts properly.
2. Examine a microscope slide of tongue tissue. Locate and describe the cells sensitive to taste. Draw and label some of these cells.
3. Get four cotton-tipped swabs. Wash out your mouth so that no residue of taste remains. Wet one of the swabs in the 5 per cent sucrose (table sugar) solution and touch it to the tip, front center, back center, and sides of your tongue. Record on a chart similar to the following where the sensation of sweetness is most intense (++), less intense (+), and not evident (o). Rinse your mouth out with water and repeat by using a fresh swab for each solution and rinsing your mouth out after each test. Try the vinegar solution, the salt solution, and then the quinine solution. Summarize your results by indicating the regions of the tongue surface that respond to the senses of sweet, sour, salt, and bitter taste on the diagram you prepared in step 1 above by labeling the regions properly.

Location and Intensity of Taste Sensations

Solution	Tip	Front center	Back center	Sides
Sweet				
Sour				
Salt				
Bitter				

QUESTIONS

1. Is there any overlapping of the different taste sensations? What is meant by the after-taste?
2. How do the salty taste buds function? What is the role of electrolytes in this?
3. How do the sweet taste buds function? Are all sweet foods safe to eat?
4. How do the bitter taste buds function? Are all poisonous substances bitter?
5. How do the sour taste buds function? What is the role of pH in this?
6. What role does the sense of taste play in bodily nutrition? Does your sense of taste lead you to eat a balanced diet?

LABORATORY 60
HOW IS MAN'S SKIN SENSITIVE TO TOUCH, PAIN, AND TEMPERATURE?

Problem:

How is man's skin sensitive to touch, pain, and temperature?

Materials:

Forceps, dissecting
Needle, dissecting or sharp pencil
Ice

Procedure:

1. Consult a model or chart showing a cross section of skin. Note the various parts of the skin and label a diagram of all these parts properly.
2. Examine a microscope slide of cross section of skin showing cells sensitive to different stimuli. Draw and label all of these you can find.
3. You have seen that there are different types of nerve endings for the sensations of heat, cold, pressure, pain. How do the number and location of these different types of nerve endings determine the sensitivity threshold of these senses? Your ability to distinguish between one- and two-point touches can help you find the relative distance between the nerve endings that enable transmission of the sense of touch.

   Blindfold your partner who will serve as your subject for this experiment. Use a pair of forceps for touching various parts of your partner's arm and face. Record results on a chart similar to the following. Spread the points of the forceps apart and touch your partner's forearm with the double points. Ask if he feels one or two points touching. If he answers "two" reduce the distance between the points until your partner reports feeling only a single point of contact. Measure and record this distance in millimeters on the chart. Repeat for each part of the body and then exchange places with your partner.

Sample Chart

Distance between touch receptors on arm and face

Area	Subject 1	Subject 2
Forearm		
Back of hand		
Palm of hand		
Tip of finger		
Forehead		
Cheek		
Nose		
Lip		

Which areas of your arm and face have the greatest number of touch receptors? How is a greater number of receptors on certain parts of your body an advantage? What other parts of the body have a large number of touch receptors? Of what advantage would this be to the individual?

4. Use a sharp pencil or needle point to test the palm of your hand for pain points. Chill the pencil lead or needle point on an ice cube and test for points that feel the cold. Are the pain points the same as the cold points? Can you explain why?
5. Draw a pail of cold and another of hot water from the taps. Add ice to a third pail of cold water. Place the ice water on your left, the cold water directly in front of you, and the hot water on your right. Immerse your left hand in the ice water and your right hand in the hot water and keep them there for about one minute. Now immerse both hands in the pail of cold water directly in front of you. Describe the sensations you experience from these actions. How do you explain? What is hot and what is cold? How do you know?

QUESTIONS

1. Is there a better way of measuring the intensity of pain and temperature sensations? If so, how? Can doctors tell which of their patients suffer more pain following surgery?
2. What questions did you answer about man's various senses?
3. What evidence did you collect which helped you to answer these questions?
4. What other questions were raised in your mind by your evidence that you would like to investigate further?
5. From your investigations, what hypotheses have been suggested that might help you answer these questions?
6. What experiments could you devise to help you find answers to some of your questions?
7. Try some similar experiments with laboratory or household animals to learn how these organisms respond to various stimuli.
8. After trying some of your ideas out, do you see any ways in which to improve your investigations?

Further Investigation

You have learned something about how man's senses work and help him in learning. What other parts of man's nervous system are there and how do these aid him to learn?

What is meant by instinct, reflex, conditioning, and goal-insight learning? How do these differ from each other? Give some examples of each of these. Which of these results in unlearned behavior? Learned? In what different ways do scientists check on the accuracy of their observations?

What are some defects and diseases to which man's senses are subject?

What seems to be the nature of a nervous impulse. How does its speed compare with that of electricity?

What different theories attempt to explain how man learns?

Is learning in animals different from that in man? If so, how? Can man change his behavior? If so, how?

What are biological clocks? Find out how they work.

Can you find out how birds migrate? Bats navigate? Porpoises navigate?

How do animals communicate with each other? How do bees communicate with each other?

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LABORATORY 61
INVESTIGATION BY CHILDREN OF SCIENCE CONCEPTS ON ADAPTATION THROUGH PROTECTIVE COLORATION

The following lesson shows how children can participate through role-playing to learn a science concept that answers the question, "How are worms adapted by protective coloration to live in their environment?"

Food is one of the basic necessities of all organisms. Can a cat or a canary go to the grocery store and buy some food? How do animals secure food? How do robins and chickens get their food? By pretending that each of you is a bird looking for a meal of worms, let us see how many "worms" you can find.

Problem:

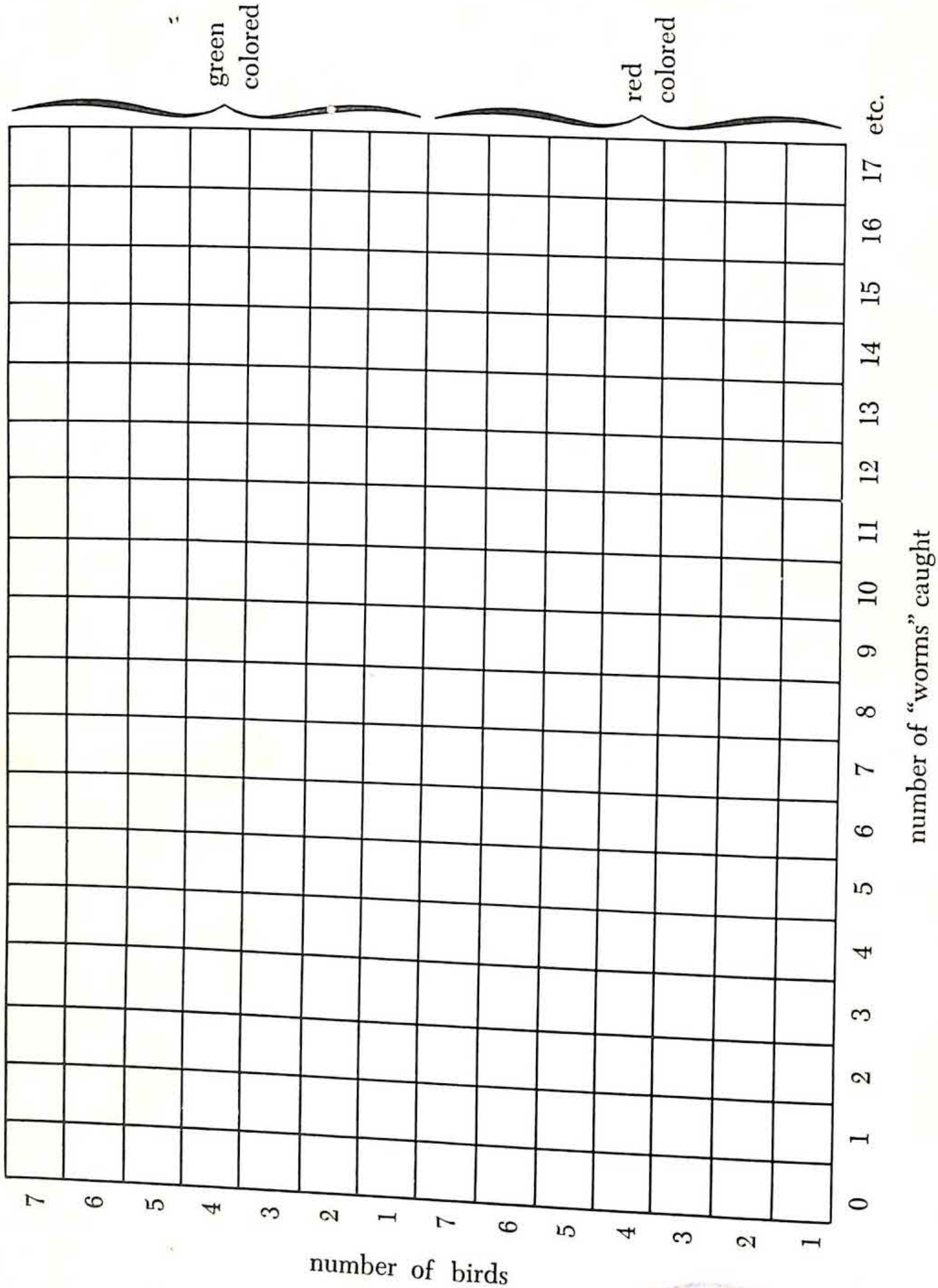
How can you demonstrate the advantage of protective coloration through a simulated "bird" and "worm" experience?

Materials:

Toothpicks or pipe cleaners colored green and red (use ink or food coloring)
Paper cups or envelopes for each student to collect the "worms"
Graph paper and pencil

Procedure: This lesson should be done with children

Show samples of the red and green "worms" to the students and ask each one to pretend he is a "bird." Divide the class into halves and let the students designate themselves as either a boy or girl bird. Use the scientific symbols of ♂ for male and ♀ for female to create interest among students. Invite the student "birds" to


green colored
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etc.
0
1
2
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7
8
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10
11
12
13
14
15
16
17
number of "worms" caught
7
6
5
4
3
2
1
7
6
5
4
3
2
1
number of birds

go to the school lawn for their next meal of "worms." Tell them that each time they find a specimen to put it in their paper cup or envelope (representing the bird's crop). When the class has hunted for a given length of time, have them return to the classroom and count their catch of "worms." Have the students look for both colors of "worms" and pick each specimen as fast as they can.

The instructor will have mixed equal numbers of both colors of "worms" and before class distributed them over a strip of grass 2 feet wide by about 60 feet long. For a class of 30 students this will give each "bird" about 2 feet of forage space, which should be numbered to correspond with the number of students. Have the students stand before their numbered site facing away from it and on a signal to "start," hunt their "worms." (Some students may be color blind). Allow the students about 1½ to 2 minutes to hunt and then signal them to "stop." (With a strong magnet, comb the grass area to pick up the remaining pipe cleaners; if toothpicks are used, the lawnmower will chop them up.)

Back in the classroom separate the "worms" and count them. On a graph prepared on the blackboard, record how many "worms" each "bird" caught. Students may use a piece of graph paper at their desks on which to copy these data.

QUESTIONS

1. What does the experiment show?
2. Does color provide protective advantage to some animals? Explain.
3. Did the males catch more "worms" than the females? Explain.

Further Investigation

What other adaptations of organisms give them protection from their enemies? List some other ways organisms are adapted to protect themselves from their enemies. After testing this activity with some children, show how you would modify it to improve it. Be creative!

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